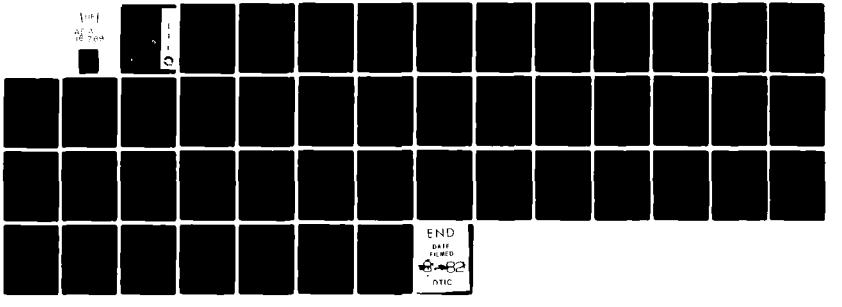
AD-A116 769 ARMY ENGINEER TOPOGRAPHIC LABS FORT BELVOIR VA F/G 8/2
DETECTING LINE-ROAD AND ROAD-INTERSECTION PATTERNS AT VARIOUS A--ETC(U)
OCT 81 J R SINGLETON, P CHEN

UNCLASSIFIED ETL-0274 NL



ETL-0274

AD A116769

Detecting line-road and road-intersection patterns at various angles

J. Robert Singleton
Pi-Fuay Chen

OCTOBER 1981

U.S. ARMY CORPS OF ENGINEERS
ENGINEER TOPOGRAPHIC LABORATORIES
FORT BELVOIR, VIRGINIA 22060

E T L

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES ETL

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ETL-0274	2. GOVT ACCESSION NO. AD-A116769	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* DETECTING LINE-ROAD AND ROAD-INTERSECTION PATTERNS AT VARIOUS ANGLES		5. TYPE OF REPORT & PERIOD COVERED Research Note 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) J. Robert Singleton Pi-Fuay Chen		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Engineer Topographic Laboratories Fort Belvoir, VA 22060		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 4A161102B52C, B, 0012
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Engineer Topographic Laboratories Fort Belvoir, VA 22060		12. REPORT DATE October 1981 13. NUMBER OF PAGES 43
14. MONITORING AGENCY NAME & ADDRESS*(if different from Controlling Office)*		15. SECURITY CLASS. *(of this report)* Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for Public Release; Distribution Unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Cartographic Feature Extraction and Recognition
Solid State Sensor Array System, Walsh Transforms
Minimum Distance Classifier

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

An extended Walsh transform technique for defecting and recognizing a set of cartographic features, such as linear roads and road intersections, at a variety of angles with the axes of the inspecting window is described.

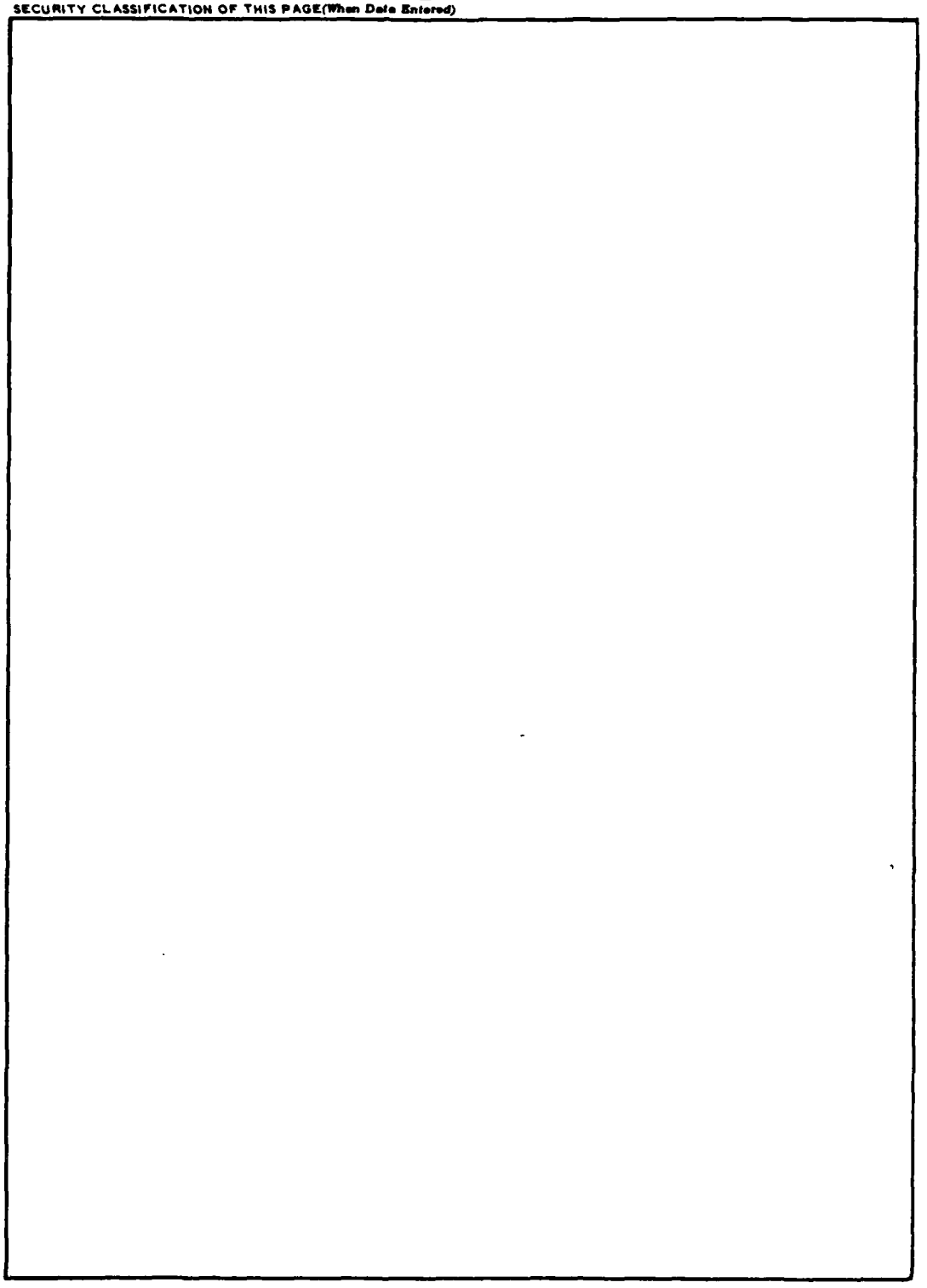
The method was implemented as software for an existing sensor array minicomputer system, which consists of a solid state array to convert optical images into electronic signals, a minicomputer as signal processor, and a computer-controlled translational stage as the imagery holder.

Each angular orientation of the cartographic features is defined as a class of pattern and classified by using two minimum distance classifiers together with some pretesting algorithms. Typical experimental results are presented and conclusions are given.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

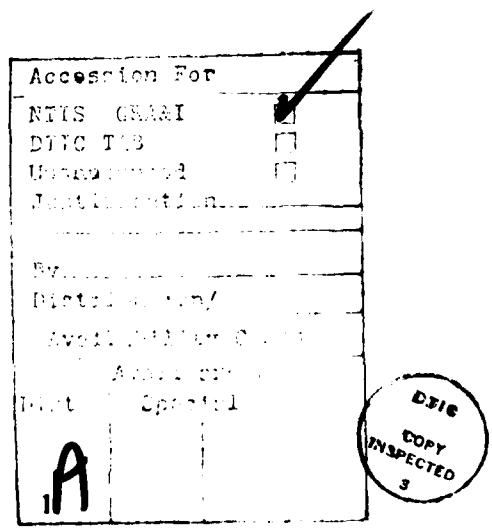


PREFACE

This work was authorized by U.S. Army Engineer Topographic Laboratories, Fort Belvoir, Virginia under FY–80 DA Project-Task Area Work Unit Number 4A161102B52CB0012 entitled, "Electronic Image Analysis for Feature Extraction."

The work was done under the supervision of Dr. F. Rohde, Team Leader, Center for Theoretical and Applied Physical Sciences; and Mr. M. Crowell, Jr., Director, Research Institute.

COL Daniel L. Lycan, CE and COL Edward K. Wintz, CE were Commanders and Directors and Mr. Robert P. Macchia was Technical Director of the Engineer Topographic Laboratories during the study period.



CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS (Continued)

DETECTING LINE-ROAD AND ROAD-INTERSECTION PATTERNS AT VARIOUS ANGLES

INTRODUCTION

Since 1979, the U.S. Army Engineer Topographic Laboratories (ETL) has been investigating discrete function technology, particularly Walsh functions, to extract and recognize a selected set of manmade cartographic features, such as road intersections, straight-line roads, and rectangular objects from aerial photographs.[1,2,3,4]

The Walsh transform was chosen because of its simplicity (Walsh functions are only two-valued, +1 or −1), resulting in simple implementation, and because Walsh functions conform to the selected set of cartographic features.

The technique was investigated by (1) using a 32- by 32-element, solid state sensor array to convert imagery into an electronic signal, which was processed in a minicomputer to yield the Walsh transform of the images;[5,6,7] and (2) using a prototype image spectrum analyzer (PISA) with a large size plasma discharge device (8.5 by 8.5 inches illuminated area with 512 electrodes each in both X and Y directions) to generate two-dimensional Walsh function patterns and produce 512 by 512 Walsh coefficients in 14 seconds.[8] The PISA produced successful results for a selected set of targets representing manmade cartographic features of the types stated above.

---

[1]P.F. Chen and W.W. Seemuller, "Signal Signatures of Topographic Features Using Analog Technology," U.S. Army Engineer Topographic Laboratories, Fort Belvoir, VA, ETL-0185, May 1979, AD-A076 110.

[2]P.F. Chen and W.W. Seemuller, "Application of Walsh Transforms for Topographic Feature Extraction Using a Sensor Array System," *IEEE Transactions on Instrumentation and Measurement*, pp 52-57, Vol IM-29, March 1980.

[3]P.F. Chen and W.W. Seemuller, "Detection of Signal Signatures of Cartographic Features," presented at 1980 Army Science Conference, also published in the *Conference Proceedings*, West Point, NY, June 1980.

[4]P.F. Chen, F.W. Rohde, and W.W. Seemuller, "Prototype Image Spectrum Analyzer (PISA) for Cartographic Feature Extraction," U.S. Army Engineer Topographic Laboratories, Fort Belvoir, VA, ETL-0204, October 1979, AD-A080 729.

[5]P.F. Chen and W.W. Seemuller, "Signal Signatures of Topographic Features Using Analog Technology," U.S. Army Engineer Topographic Laboratories, Fort Belvoir, VA, ETL-0185, May 1979, AD-A076 110.

[6]P.F. Chen and W.W. Seemuller, "Application of Walsh Transforms for Topographic Feature Extraction Using a Sensor Array Syster.." *IEEE Transactions on Instrumentation and Measurement*, pp 52-57, Vol Im-29, March 1980.

[7]P.F. Chen and W.W. Seemuller, "Detection of Signal Signatures of Cartographic Features," presented at 1980 Army Science Conference, also published in the *Conference Proceedings*, West Point, NY, June 1980.

[8]P.F. Chen, F.W. Rohde, and W.W. Seemuller, "Prototype Image Spectrum Analyzer (PISA) for Cartographic Feature Extraction," U.S. Army Engineer Topographic Laboratories, Fort Belvoir, VA, ETL-0204, October 1979, AD-A080 729.

The sensor array minicomputer system provides a variable image threshold that results in better control of the input images. The cartographic features as described with background scenes and noise were extracted successfully from aerial imagery. Since the sensor array minicomputer system proved superior to the PISA in this application, a classifier was implemented for the former to become a semi-automated cartographic feature extraction and recognition system.[9]

In the referenced research, the objective was to detect road intersections and straight-line roads oriented to have 0, 45, 90, and 135 degree angles with respect to the horizontal axis of the view window only. In this report, a refined scheme is described to extend the Walsh transform processing technique to detect road intersections and straight-line roads at a variety of angles with respect to the axes of the window. The heart of the scheme was implemented as software for an existing experimental system consisting of a solid state sensor array as an opto-electronic converter, a minicomputer as a signal processor, and a computer-controlled translational stage as the imagery holder. Successful extraction and recognition results are presented for a selected set of the stated cartographic features using this experimental system. Finally, conclusions are given.

SYSTEM CONFIGURATION

The present system configuration is shown in figure 1. A 9– by 9–inch aerial transparency, mounted on a stage translatable in both the X and Y directions, is illuminated by a d.c. – powered, white light source. A section of the transparency is then imaged onto a Reticon 32– by 32–element, solid state array sensor. The image is sampled and digitized into 1024 elements at 1024 gray levels and fed into a Hewlett-Packard (HP) 2108 minicomputer. A variable threshold is then applied to the digitized image, reducing it to a two-tone black-and-white image. The white pixels are assigned the value 100, and the black elements are assigned 0. This two-valued image is then transformed to generate a two-dimensional Walsh transform coefficient matrix composed of 32 by 32 elements. The low order, 16 by 16 coefficients are then applied to the software classification algorithm, which will be described later. This algorithm classifies the image into 1 of 16 angles for straight-line roads or into 1 of 4 angles of road intersections, or "not recognized" if the image does not fit either classification.

[9]P.F. Chen and W.W. Seemuller, "Detection of Signal Signatures of Cartographic Features," Presented at 1980 Army Science Conference, also published in the *Conference Proceedings*, West Point, NY, June 1980.

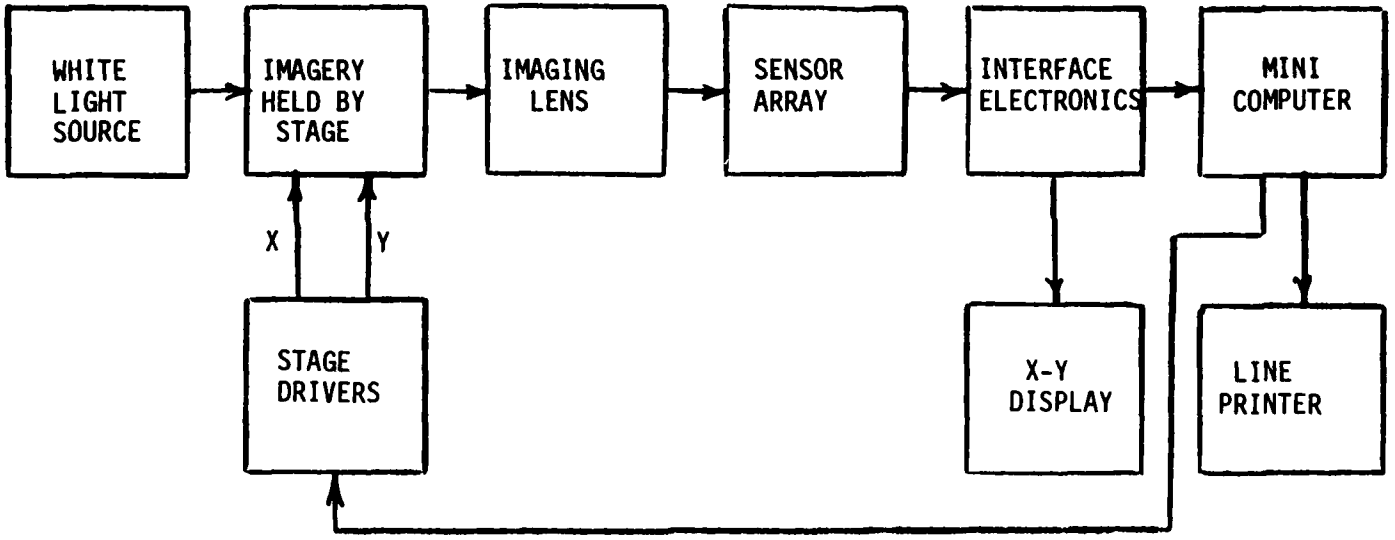


FIGURE 1. System Block Diagram.

SOFTWARE CLASSIFIER

Two arrays are passed to the software classification subroutine; the Walsh transform coefficient matrix (IXFRM) and the post-threshold image matrix. First, line roads are separated from road intersections to form two independent large cases.

To differentiate between line roads and intersections, one must summarize the first 8 rows and 8 columns of the transform matrix, such that

$$C_j = \sum_{j=1}^{16} \qquad R_i = \sum_{j=1}^{16} T(i, j)$$

where

T (i, j) is the i th row and j th column element of the Walsh coefficient matrix.

These summations are then used as the first step in differentiating between line roads and intersections by using the formula

$$A = \frac{\left| C_1 - T(1, 1) \right|}{\left| T(1, 1) \right|} \quad , B = \frac{\left| R_1 - T(1, 1) \right|}{\left| T(1, 1) \right|}$$

If $A > 0.7$, $B > 0.7$, $C_1 \geq 50$, and $R_1 \geq 50$, then the image is defined as a road intersection.

This test will recognize an intersection for all cases, except one. When an intersection is alined at 45 degrees to the viewing axis, another test must be made. From the image and Walsh transform of an intersection oriented at 45 degrees, it can be observed that R_1 and C_1 are both rather small in magnitude (both less than 50, which was the minimum value for an image to be classified as an intersection in the last test). However, the sum of diagonal transform coefficents [T (1, 1) + T (2, 2) + . . . + T (16, 16)] is a reasonably large quantity.

With the sum of the first five diagonal coefficients defined as

$$D = \sum_{i=j=1}^{5} T(i, j),$$

an image is recognized as an "intersection at 45 degrees" if one of the following expressions is met:

$$\text{If } \frac{|T(2,3)|}{|T(1,1)|} > 0.35 \text{ AND } \frac{|T(2,2)|}{|T(1,1)|} < 0.3 \text{ AND } T(2,3) + T(1,1) > 40$$

OR

$$\frac{|T(3,2)|}{|T(2,3)|} > 0.35 \text{ AND } \frac{|T(2,2)|}{|T(1,1)|} < 0.3 \text{ AND } T(1,1) + T(3,2) > 40$$

OR

$$D > 40 \text{ AND } \frac{|T(3,3)|}{|T(1,1)|} > 0.35 \text{ AND } \frac{|T(2,2)|}{|T(1,1)|} < 0.3;$$

The above tests in combination with a minimum distance classifier will effectively detect 0 and 45 degree angles. However, another test is necessary, and that one is performed in the image domain.

Let

$$C = \sum_{m=1}^{32} A(1,m) \qquad D = \sum_{n=1}^{32} A(32,n)$$

where A (1, m) and A (32, n) with m, n = 1, 2, . . . , 32 are the lst and 32nd rows of the input pattern in the image domain. Increment m and n, and compute C and D until C = D = 300. Then, if n > m, the image is at a 22.55 degree angle, and if m > n, it is at 67.5 degrees.

The algorithm for determining the angle of line roads will be discussed next. The image can be divided into four quadrants (see figure 2).

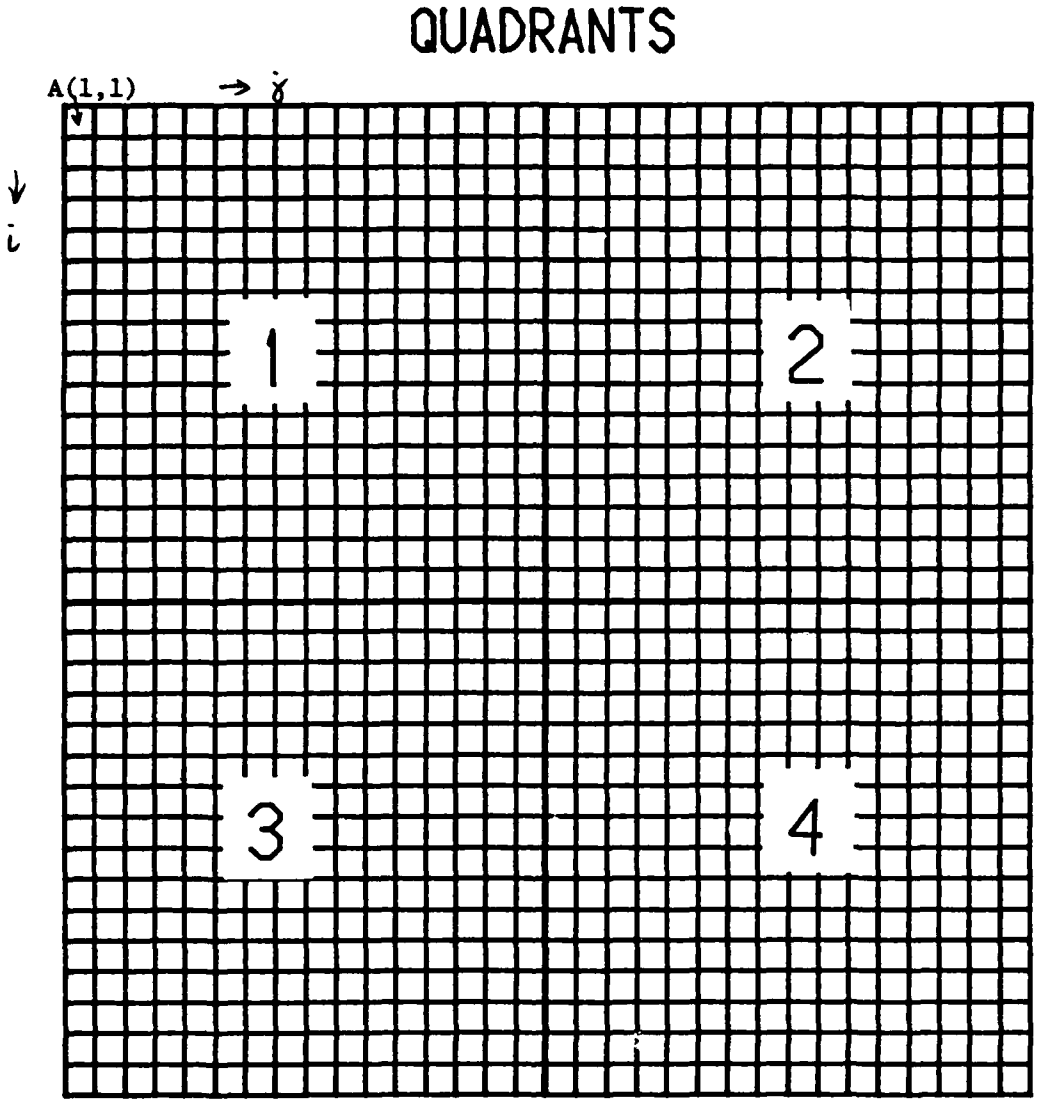


FIGURE 2. Input Image Array Divided Into 4 Quadrants.

Let

$$M_1 = \sum_{i=1}^{16} \sum_{j=1}^{16} A(i,j)$$

$$M_2 = \sum_{i=1}^{16} \sum_{j=17}^{32} A(i,j)$$

$$M_3 = \sum_{i=17}^{32} \sum_{j=1}^{16} A(i,j)$$

$$M_4 = \sum_{i=17}^{32} \sum_{j=17}^{32} A(i,j)$$

where A (i, j) is the input image array.

Several tests are then applied to determine whether the angle of the image lies (a) between 0 and 90 degrees, or (b) between 90 and 180 degrees.

TEST 1

If $M_1 = 0$, and M_2, M_3, and M_4 do not equal 0, then the angle is less than 90 degrees.

If $M_2 = 0$, and M_1, M_3, and M_4 do not equal 0, then the angle is between 90 and 180 degrees.

If $M_3 = 0$, and M_1, M_2, and M_4 do not equal 0, then the angle is between 90 and 180 degrees.

If $M_4 = 0$, and M_1, M_2, and M_3 do not equal 0, then the angle is less than 90 degrees.

If the angle of the image falls into one of the above categories, the routine then proceeds to the Minimum Distance Classifier (MDC). Otherwise, it proceeds to TEST 2.

TEST 2

(A) If $M_1 = M_2 = 0$, and M_3 and M_4 do not equal 0, then compute M_3 and M_4 until $M_3 = M_4 = 1000$, where

I_{M_3} is the net increment of the subscript used for the outer summation to compute M_3 to produce a sum of 1000.

I_{M_4} is similar to I_{M_3}, but for M_4

If $I_{M_3} \geq I_{M_4}$, the angle is less than or equal to 90 degrees.

$I_{M_3} < I_{M_4}$, the angle is between 90 and 180 degrees.

Proceed to the MDC routine.

(B) If $M_3 = M_4 = 0$, and M_1 and M_2 do not equal 0, then compute M_1 and M_2 until $M_1 = M_2 = 1000$, where I_{M_1} and I_{M_2} are similar to those (A) above.

If $I_{M_1} \geq I_{M_2}$, the angle is less than or equal to 90 degrees.

$I_{M_1} < I_{M_2}$, the angle is between 90 and 180 degrees.

Proceed to the MDC routine.

If neither of the conditions in (A) or (B) were true, then do TEST 3.

TEST 3

(A) If $M_1 = M_3 = 0$, M_2 and M_4 do not equal 0, then compute M_2 and M_4 until $M_2 = M_4 = 1000$. Let J_{M_2} and J_{M_4} be the net increment of the subscript used to compute M_2 and M_4 respectively.

If $J_{M_2} \geq J_{M_4}$, the angle is less than or equal to 90 degrees.

If $J_{M_2} < J_{M_4}$, the angle is between 90 and 180 degrees.

Proceed to MDC routine.

(B) If $M_2 = M_4 = 0$, and M_1 and M_3 do not equal 0, then compute M_1 and M_3 until $M_1 = M_3 = 1000$, where J_{M_1} and J_{M_3} are similar to those in (A).

If $J_{M_1} \geq J_{M_3}$, the angle is less than or equal to 90 degrees.

If $J_{M_1} < J_{M_3}$, the angle is between 90 and 180 degrees.

Proceed to the MDC routine.

TEST 4

This test is performed if each of the four quadrants contains at least one white pixel.

If $M_1 = 0$, $M_2 = 0$, $M_3 = 0$, or $M_4 = 0$, then proceed to TEST 5.

If $T(2, 2) < 0$, the image is less than 90 degrees.

If $T(2, 2) > 0$, the image is greater than 90 degrees.

Proceed to the MDC routine.

TEST 5

If M_1 does not equal 0, and $M_2 = M_3 = M_4 = 0$, then the angle is less than 90 degrees.

If M_4 does not equal 0, and $M_1 = M_2 = M_3 = 0$, then the angle is less than 90 degrees.

If M_2 does not equal 0, and $M_1 = M_3 = M_4 = 0$, then the angle is between 90 and 180 degrees.

If M_3 does not equal 0, and $M_1 = M_2 = M_4 = 0$, then the angle is between 90 and 180 degrees.

Proceed to the MDC routine.

If the image has not passed any of the above tests, then it is classified as "not recognized."

THE MINIMUM DISTANCE CLASSIFIERS (MDC)

Separate minimum distance classifiers (MDC) were designed for both linear-road patterns and road-intersection patterns respectively. The set of linear-line roads consists of 16 classes, and each class represents a linear road oriented at a particular angle with respect to the axes of the inspecting window. Likewise, the set of road intersections consisted of four classes. Assuming that these classes are representable by prototype (or reference) patterns $\underline{z}_1, \underline{z}_2, \ldots, \underline{z}_m$, then for linear roads, $m = 16$ and for road intersections, $m = 4$.

The Eclidean distance between an arbitrary pattern vectors $\underline{x}$ and the i th prototype is given by

$$D_i = \left|\left| \underline{x} - \underline{z}_i \right|\right| = \sqrt{(\underline{x} - \underline{z}_i)^T (\underline{x} - \underline{z}_i)},$$

where

$$(\underline{x} - \underline{z}_i)^T \text{ is the transpose of } (\underline{x} - \underline{z}_i).$$

A minimum distance classifier computes the distance from a pattern $\underline{X}$ of unknown classification to the prototype of each class and assigns the pattern to the class to which it is closest. In other words, $\underline{X}$ is assigned to class "i" if $D_i < D_j$ for all $j \neq i$.

To establish the prototypes $\underline{z}_1, \underline{z}_2, \ldots, \underline{z}_m$, one should use the first 8 rows and 8 columns of the summarized Walsh transform coefficients, $R_1, R_2 \ldots, R_8, C_1, C_2 \ldots, C_8$, as measurement vectors. They are expressed as

$$\underline{z}_i = [\, R_{1i}, R_{2i}, \ldots, R_{8i}, C_{1i}, C_{2i}, \ldots C_{8i} \,]^T$$

Sixteen prototypes for linear roads having incremental angles of 11.25 degrees (starting at 0 degree with respect to the horizontal axis of the window) were obtained using the above equation. Likewise, four prototypes for road intersections at angles of 0, 22.5, 45.0, and 67.5 degrees with respect to the horizontal axis of the window were computed. These $\underline{z}_i$ were then used to compute D_i and classify the incoming unknown pattern, $\underline{X}$. The complete software package for this method is attached in the appendix.

EXPERIMENTAL RESULTS

Targets representing linear roads and road intersections at various angles with respect to the axes of the window were constructed on a glass plate. The targets were used as input test images. The glass plate was mounted on a computer-controlled translational stage so that the relative position of the images against the surface of the solid state array can be adjusted arbitrarily.

In figures 3 through 18, the original images in spatial domain, the recognition results, and the Walsh transforms for linear roads at a variety of orientation with the window are shown. The experimental results for road intersections having various angles with the axes of the window are shown in figures 19 through 22. Correct recognition was obtained for all cases.

A random translation of these images against the window was also tested. It was discovered that for the well-defined images, such as targets used for this experimentation, no misclassification was obtained. In figures 23 and 24, the typical test results for a linear road and a road intersection translated away from their center position. Again correct recognition was obtained for both cases. Other tests for translation were performed and similar results were obtained.

The detectable angular resolutions for the line roads and the road intersections were found to be 11.25 and 22.5 degrees, respectively. When the test images were corrupted by a large amount of noise, the method failed to produce correct recognition results. The amount of noise may be reduced by thinning techniques. However, the thinning techniques were not tested during the experiments.

CONCLUSIONS

1. Noise-free linear cartographic features, such as roads and road intersections at a variety of angles with the axes of the inspecting window, can be detected using an extended Walsh transform processing technique.

2. Minimum distance classifiers together with some pretesting conditions were found to be very suitable for this application.

3. All the test images (targets) at a variety of angles and also with arbitrary translations were detected and classified correctly.

4. The detectable angular resolutions for linear roads and road intersections were found to be 11.25 and 22.5 degrees, respectively.

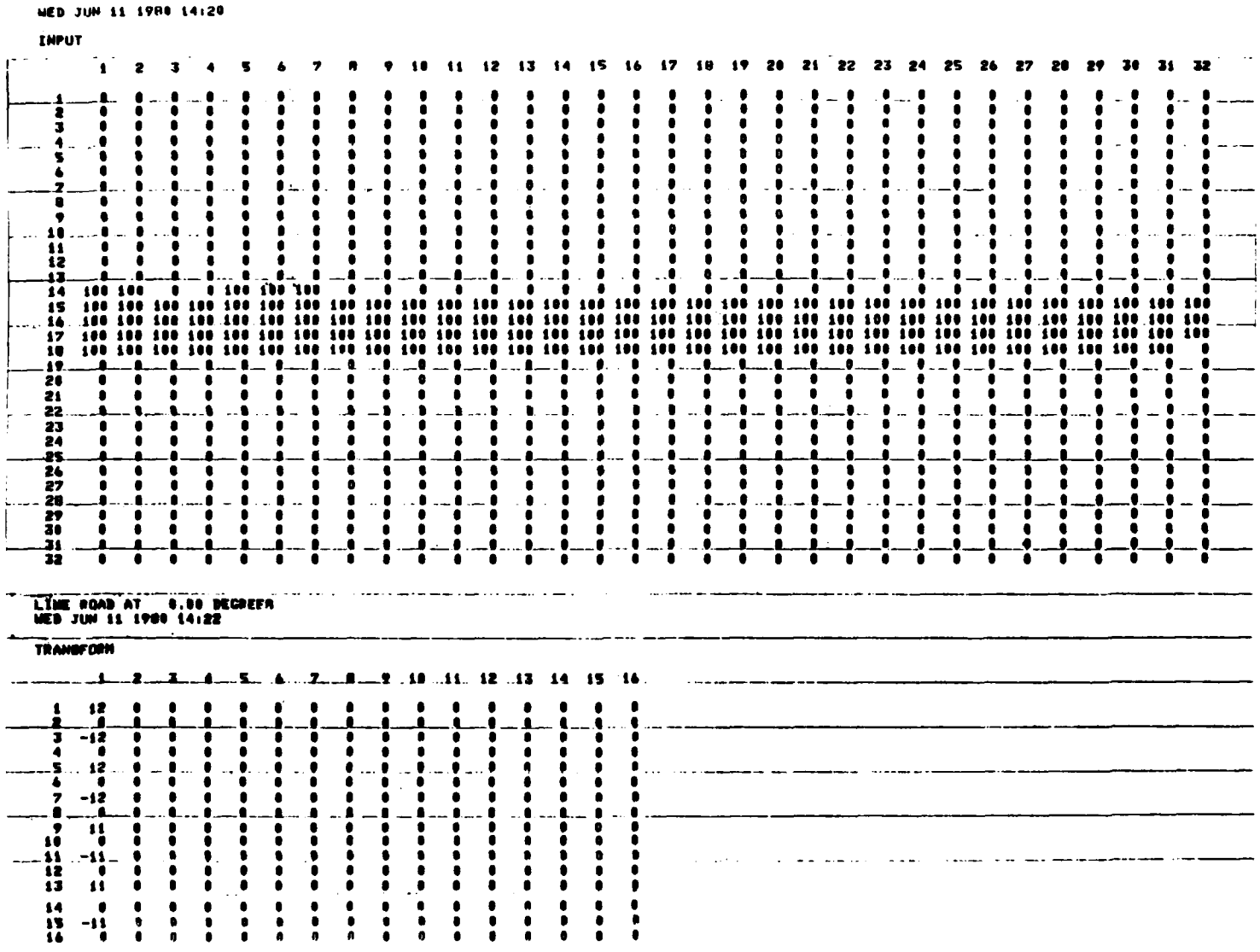


FIGURE 3. Spatial Signaturc, Recognition Result, and Walsh Transform for Line Road at 0 Degree.

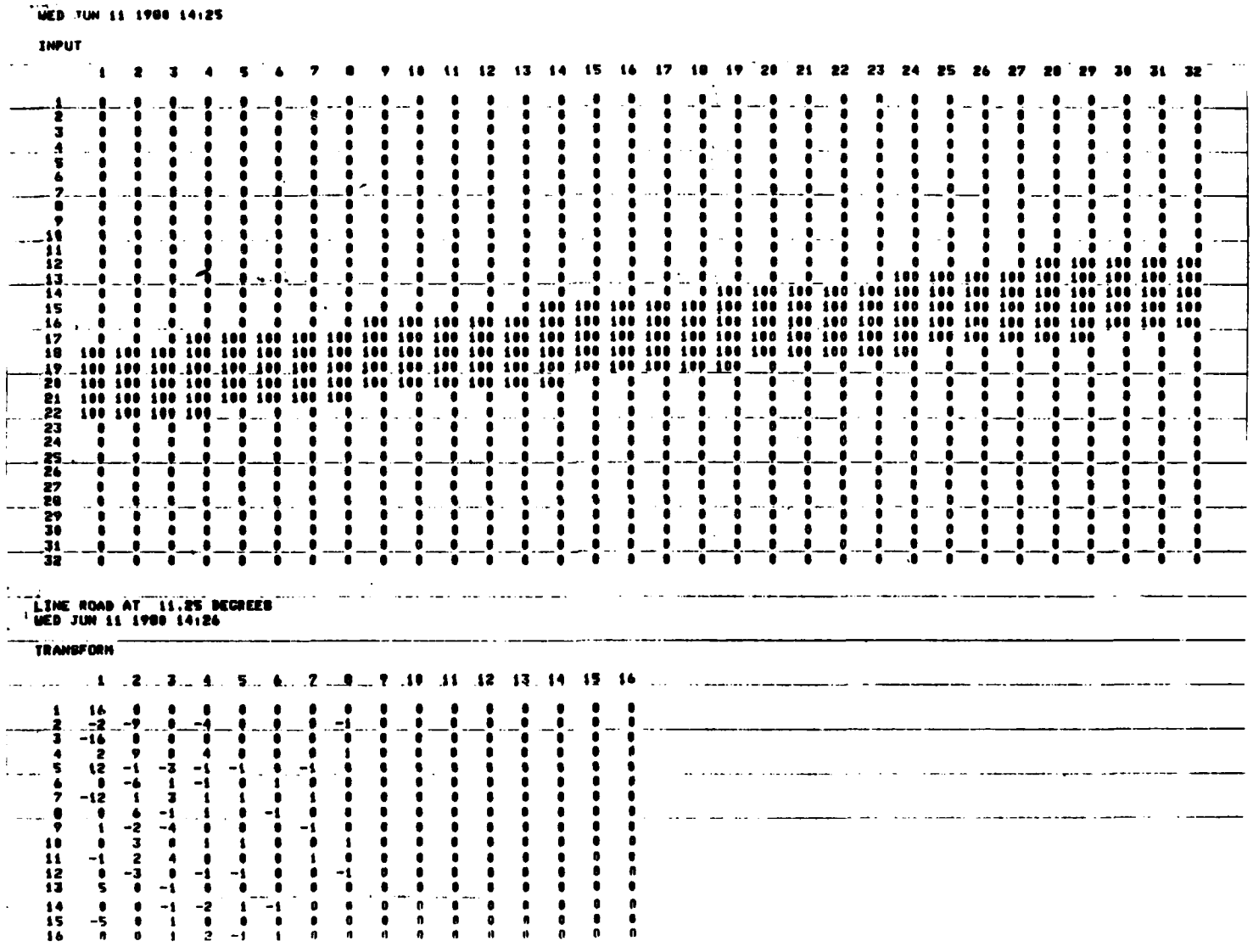


FIGURE 4. Spatial Signature, Recognition Result, and Walsh Transform for Line Road at 11.25 Degrees.

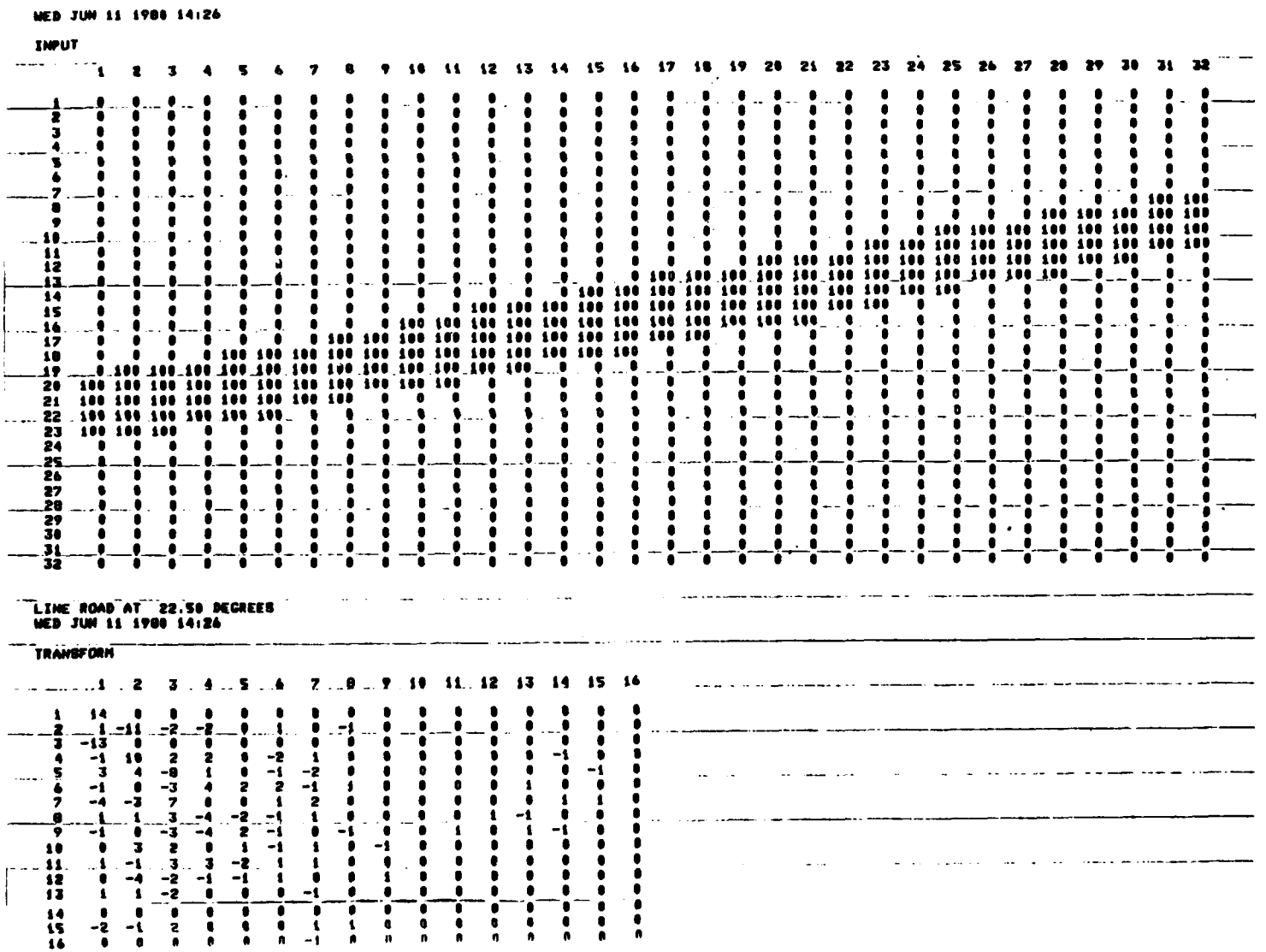


FIGURE 5. Spatial Signature, Recognition Result, and Walsh Transform for Line Road at 22.5 Degrees.

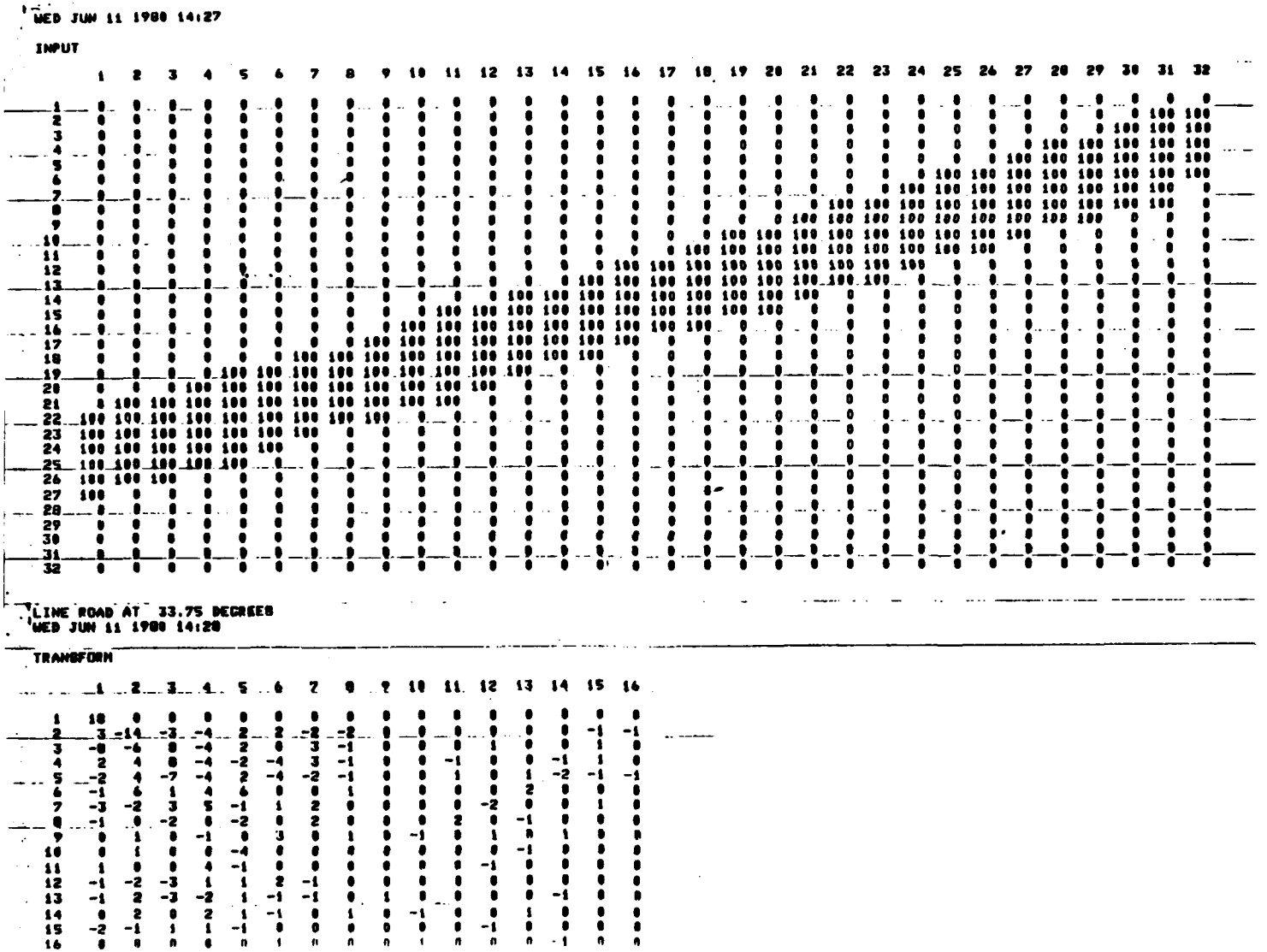


FIGURE 6. Spatial Signature, Recognition Result, and Walsh Transform for Line Road at 33.75 Degrees.

WED JUN 11 1980 14:29

INPUT

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100	100
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100	100	100
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100	100	100	100
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100	100	100	100
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100	100	100	100	100
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100	100	100	100	100	100	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100	100	100	100	100	100	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100	100	100	100	100	100	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100	100	100	100	100	100	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100	100	100	100	100	100	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100	100	100	100	100	100	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100	100	100	100	100	100	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100	100	100	100	100	100	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	100	100	100	100	100	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	100	100	100	100	100	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	100	100	100	100	100	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	100	100	100	100	100	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	100	100	100	100	100	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	100	100	100	100	100	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	100	100	100	100	100	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	100	100	100	100	100	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	100	100	100	100	100	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	100	100	100	100	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	100	100	100	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	100	100	100	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	100	100	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

LINE ROAD AT 45.00 DEGREES
WED JUN 11 1980 14:29

TRANSFORM

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	31	1	-2	0	-2	0	-2	0	0	0	0	0	0	0	0	0
2	0	-25	-2	-3	0	7	-1	-2	0	1	0	0	0	3	0	-1
3	-3	-3	19	0	-2	2	7	0	0	0	-2	0	0	1	3	0
4	0	-2	1	-13	-3	-2	0	-2	0	0	0	3	-2	-1	0	-1
5	-2	0	-2	-3	0	0	-1	0	0	0	0	1	3	0	0	0
6	0	7	2	-2	0	-4	0	-1	0	0	0	0	0	-2	0	0
7	-2	-1	7	0	-1	0	0	0	0	-1	0	-1	0	0	1	0
8	0	-2	0	-2	0	-1	0	2	3	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	3	-3	0	0	0	0	0	0	0
10	0	1	0	0	0	0	-1	0	0	1	1	0	0	0	0	0
11	0	0	-2	0	0	0	0	-1	0	1	0	0	0	0	0	0
12	0	0	0	3	1	0	0	0	0	0	0	-1	0	0	0	0
13	0	0	0	-1	3	0	0	0	0	0	0	0	1	0	0	0
14	0	3	1	-1	0	-2	0	0	0	-1	0	0	0	-1	-1	0
15	0	0	3	0	0	0	1	0	0	0	0	0	0	-1	0	0
16	0	-1	0	-1	0	0	0	0	0	0	0	0	0	0	0	0

FIGURE 7. Spatial Signature, Recognition Result, and Walsh Transform for Line Road at 45 Degrees.

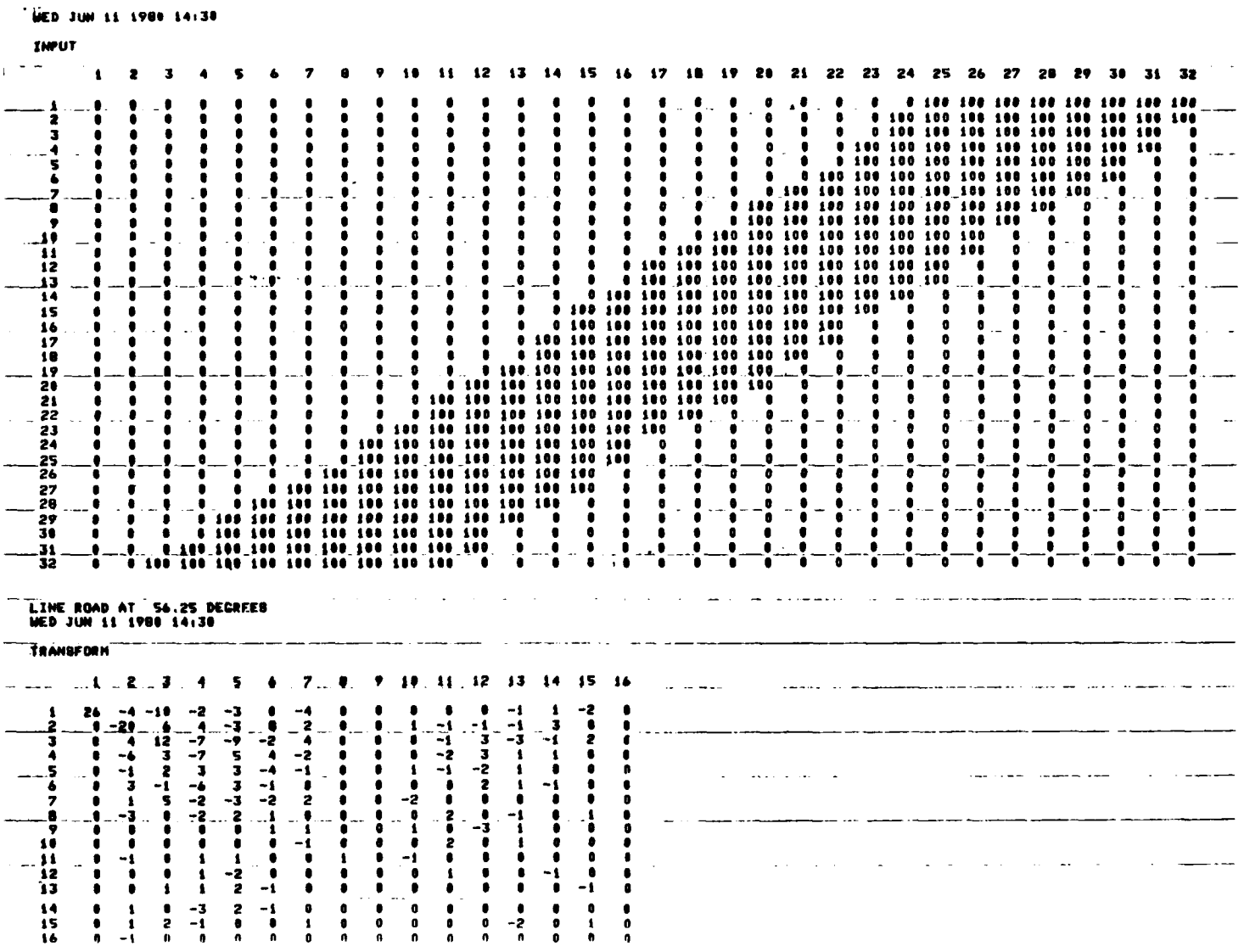


FIGURE 8. Spatial Signature, Recognition Result, and Walsh Transform for Line Road at 56.25 Degrees.

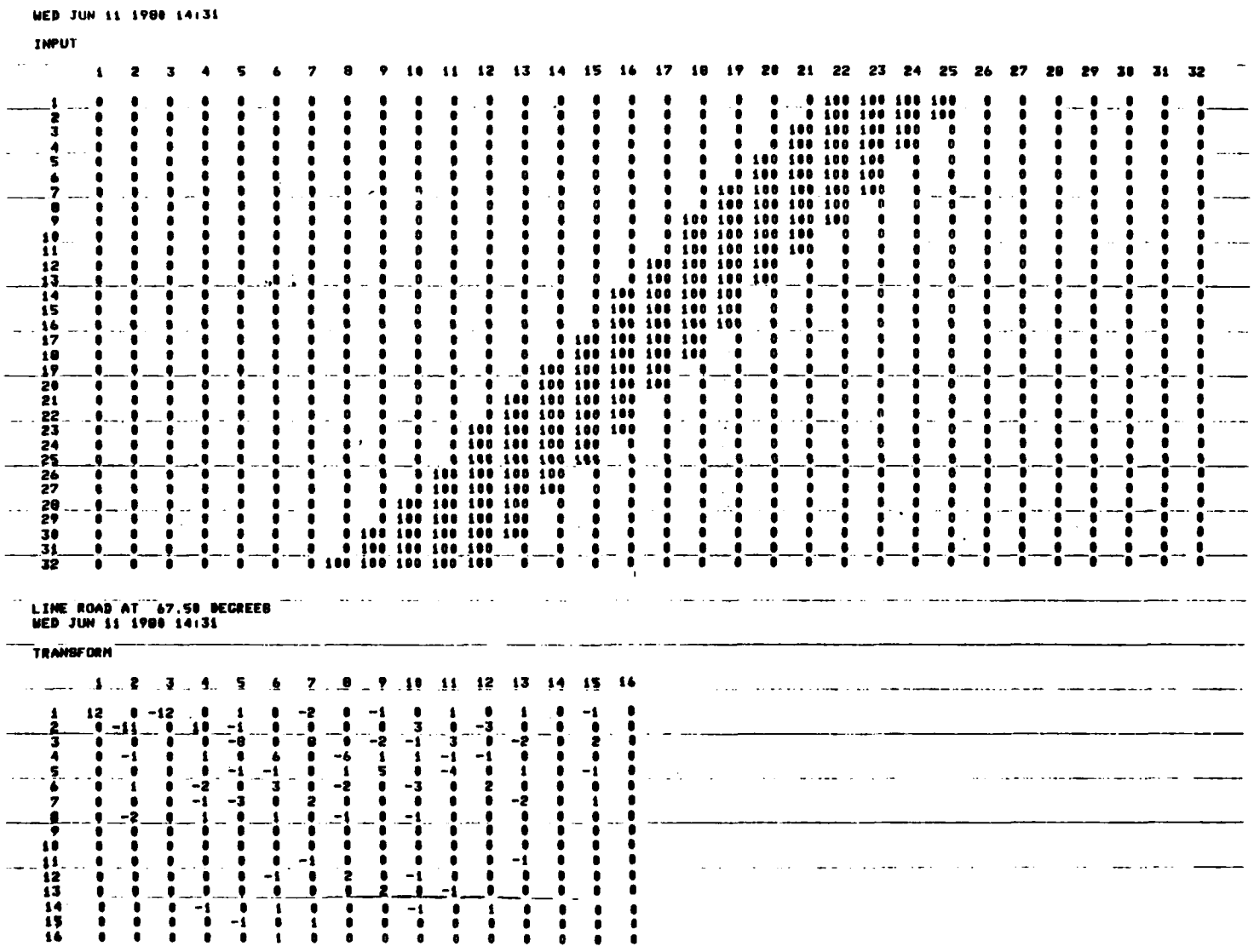


FIGURE 9. Spatial Signature, Recognition Result, and Walsh Transform for Line Road at 67.5 Degrees.

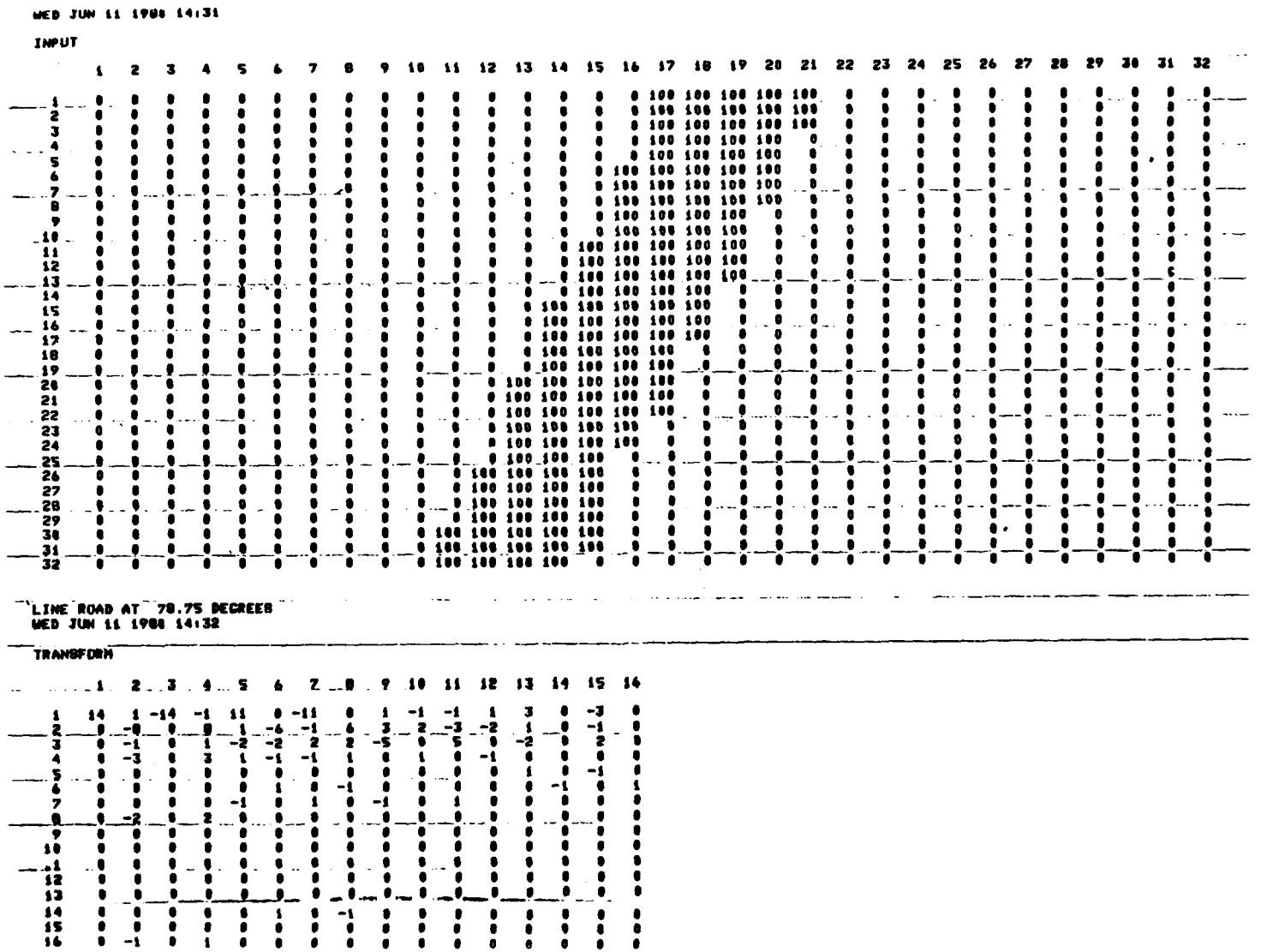


FIGURE 10. Spatial Signature, Recognition Results, and Walsh Transform for Line Road at 78.75 Degrees.

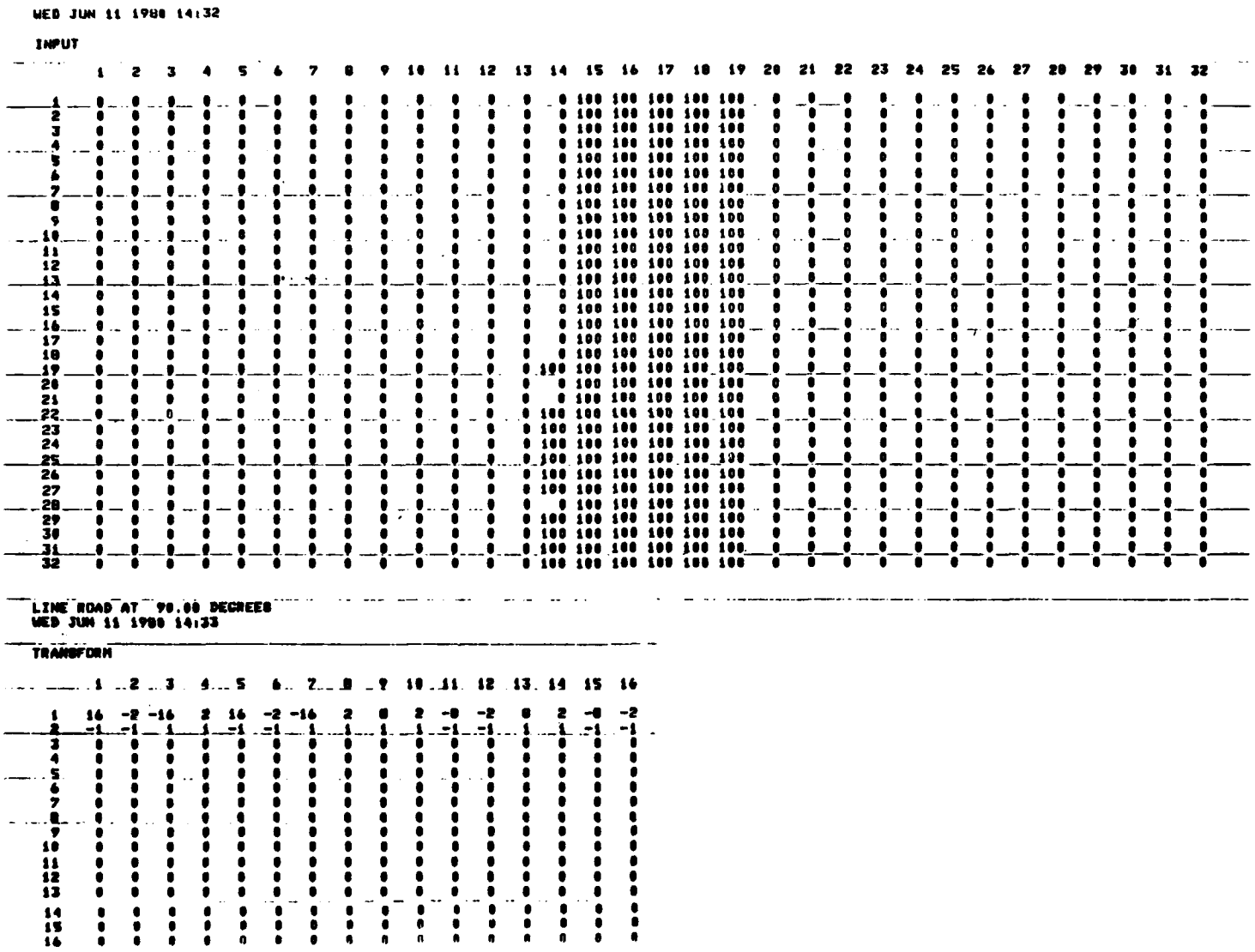


FIGURE 11. Spatial Signature, Recognition Result, and Walsh Transform for Line Road at 90 Degrees.

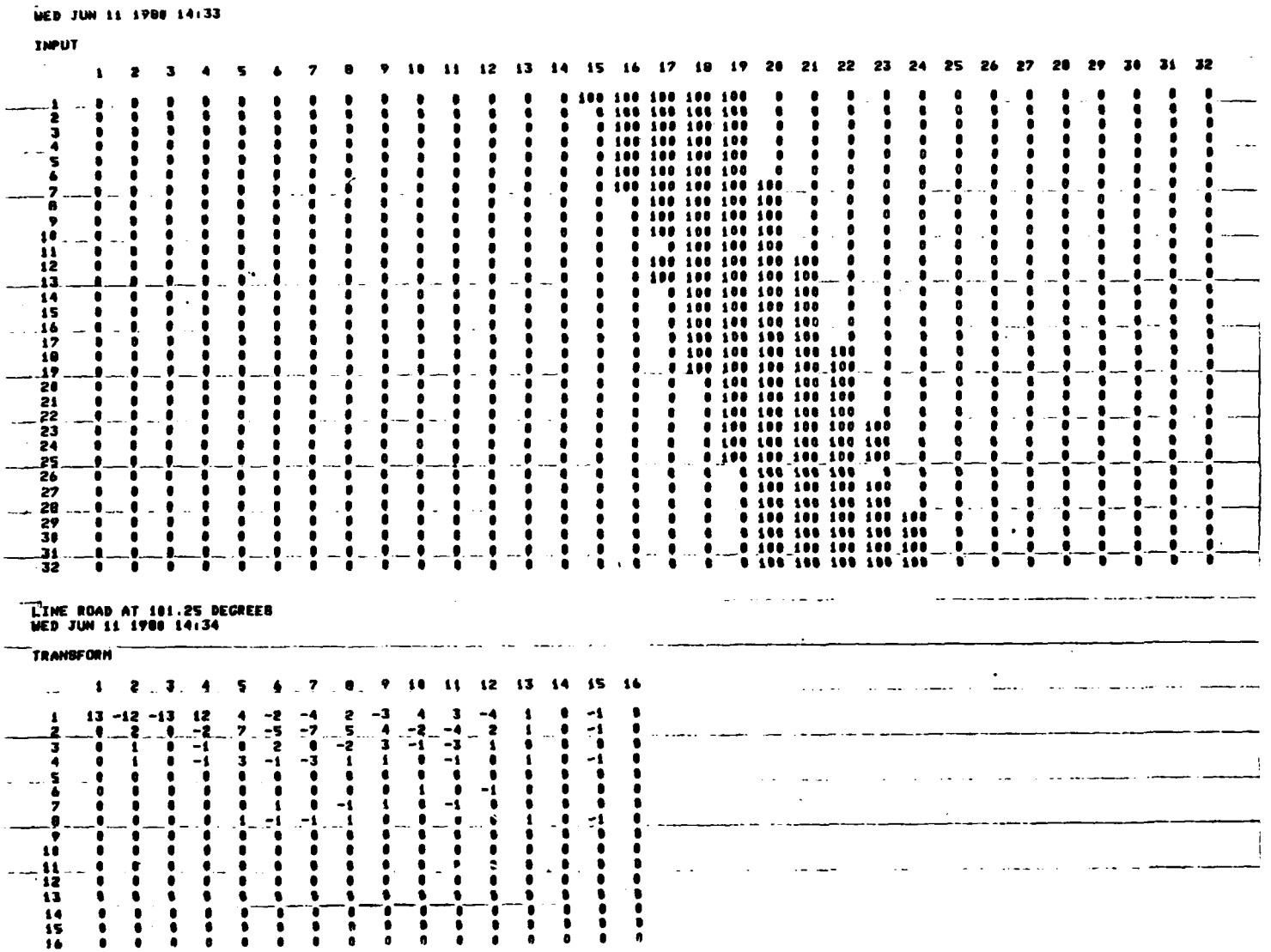


FIGURE 12. Spatial Signature, Recognition Result, and Walsh Transform for Line Road at 101.25 Degrees.

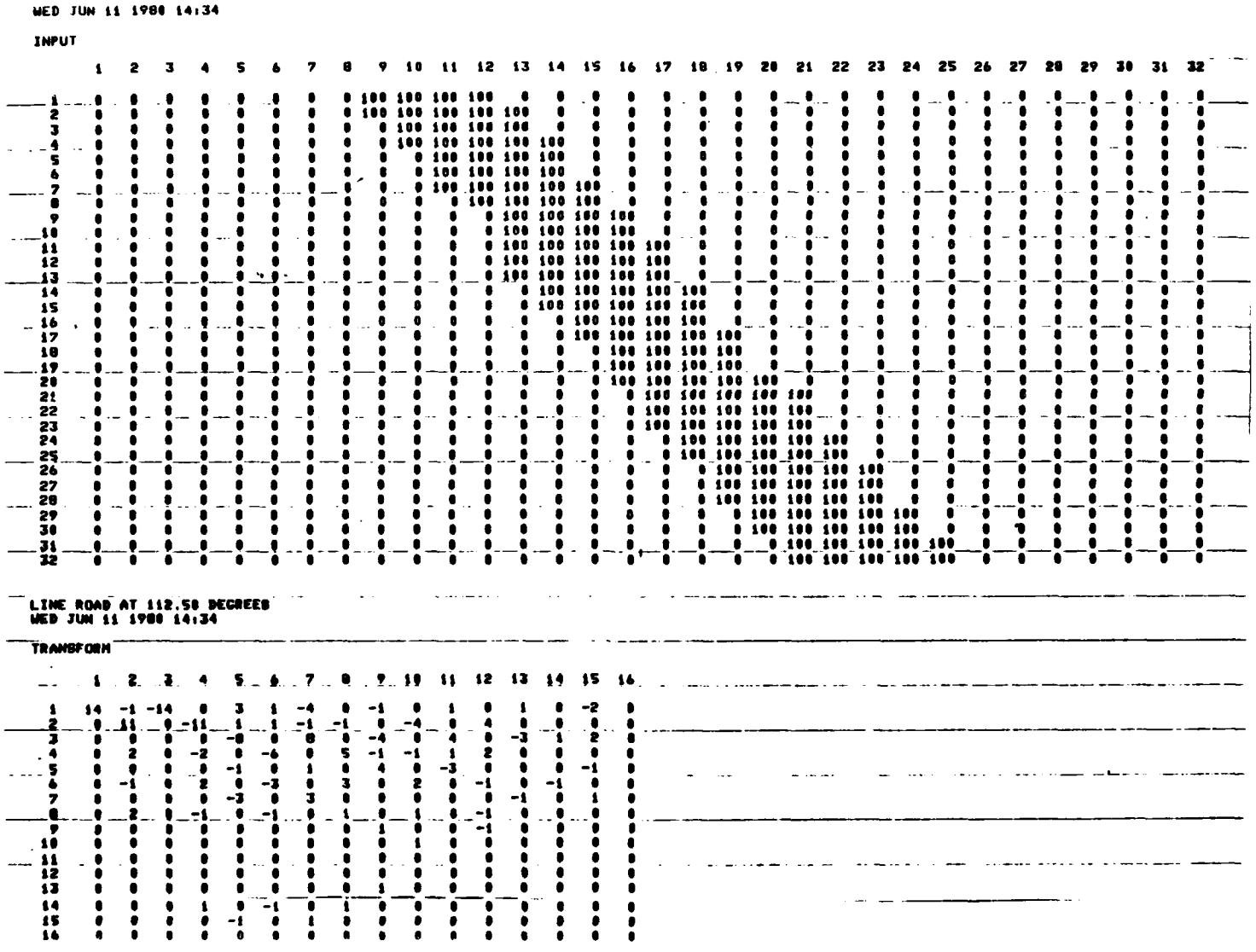


FIGURE 13. Spatial Signature, Recognition Result, and Walsh Transform for Line Road at 112.5 Degrees.

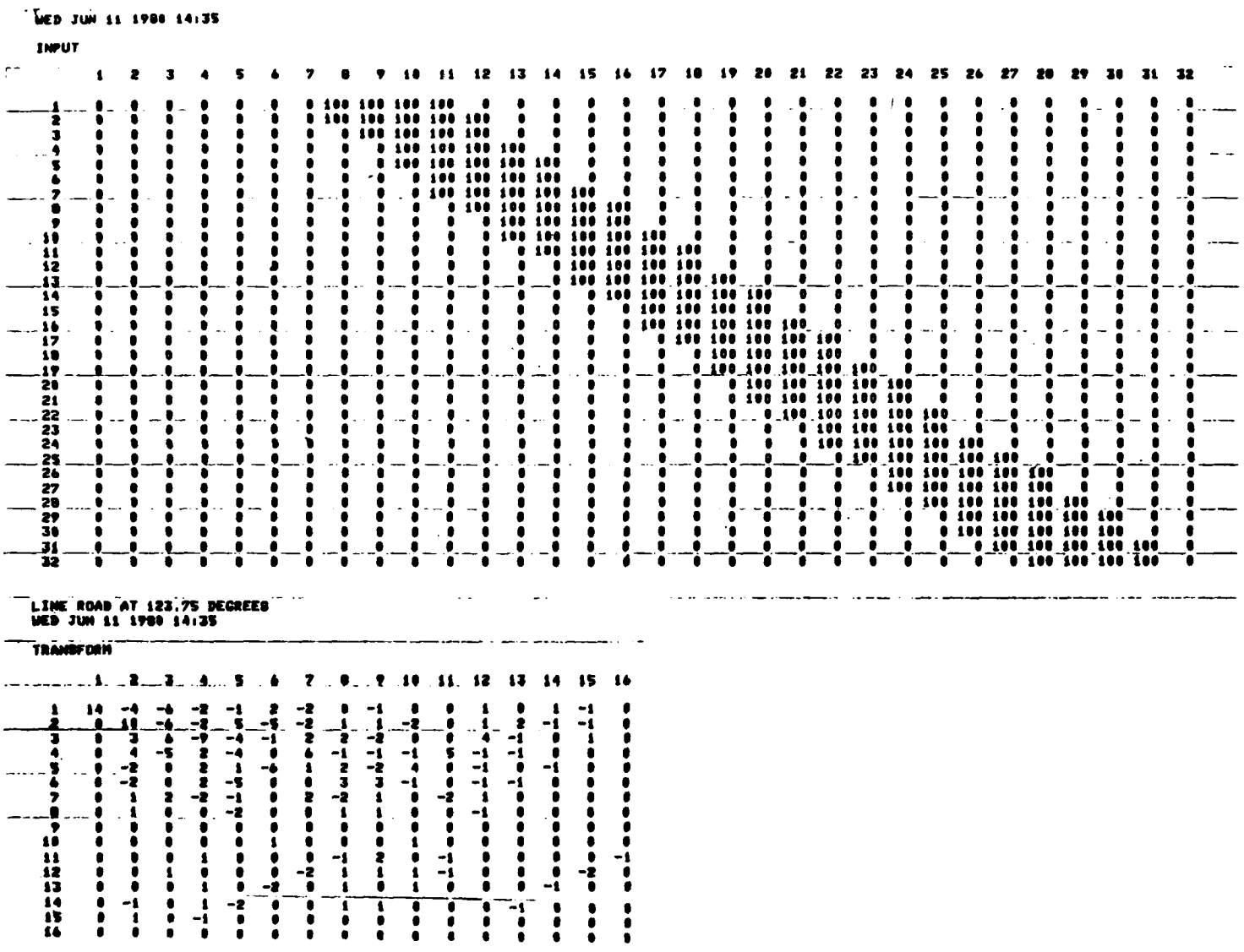


FIGURE 14. Spatial Signature, Recognition Result, and Walsh Transform for Line Road at 123.75 Degrees.

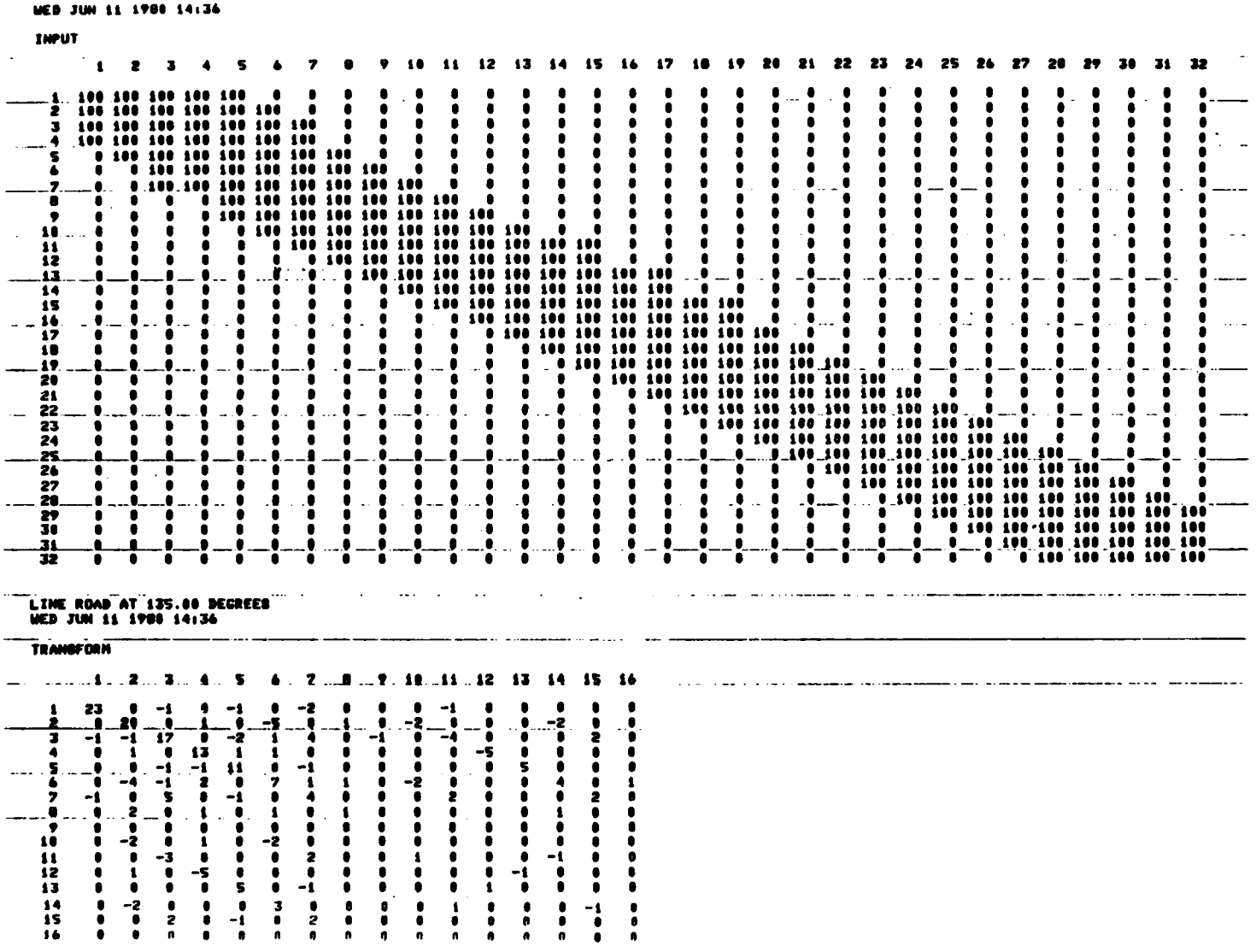


FIGURE 15. Spatial Signature, Recognition Results, and Walsh Transform for Line Road at 135 Degrees.

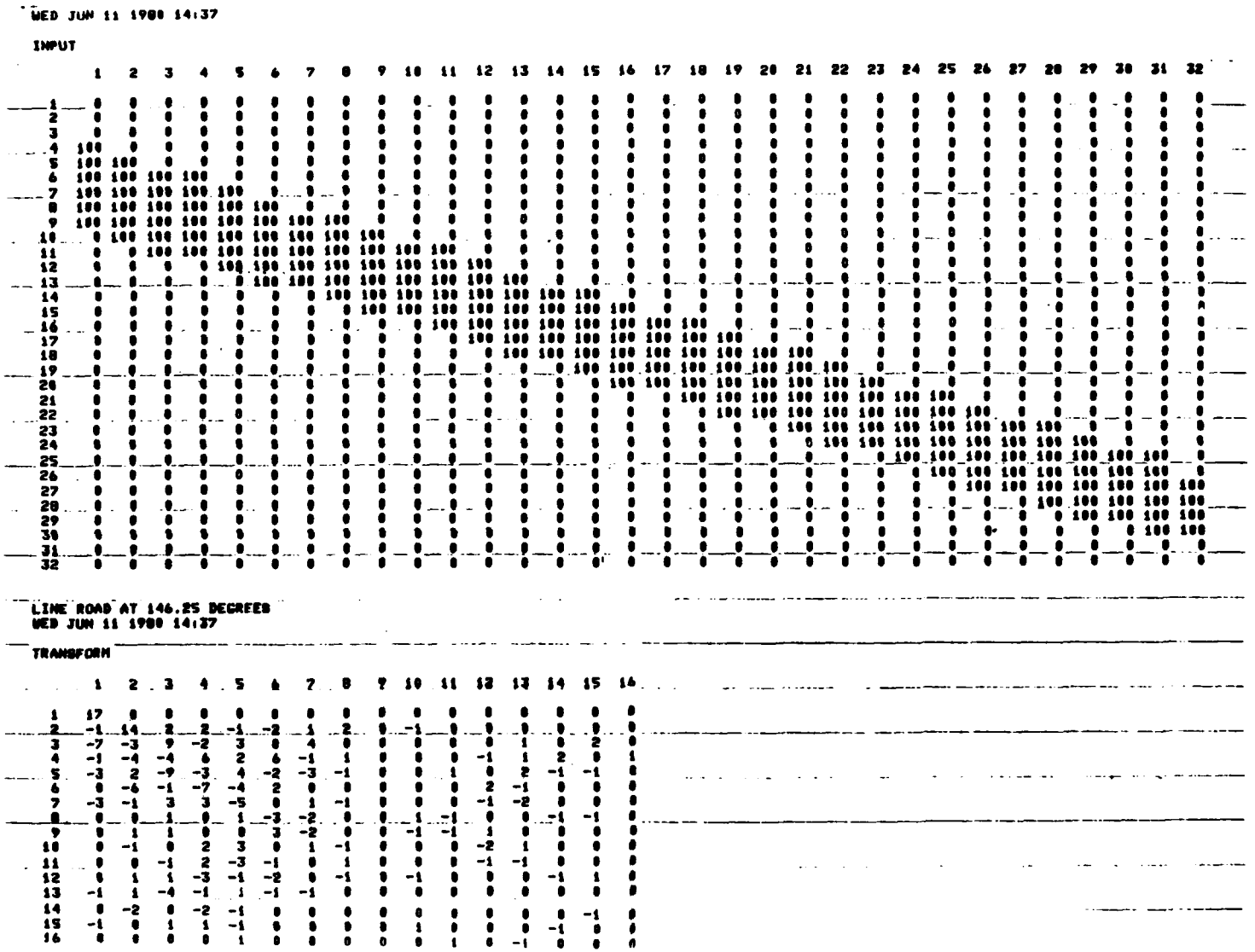


FIGURE 16. Spatial Signature, Recognition Result, and Walsh Transform for Line Road at 146.25 Degrees.

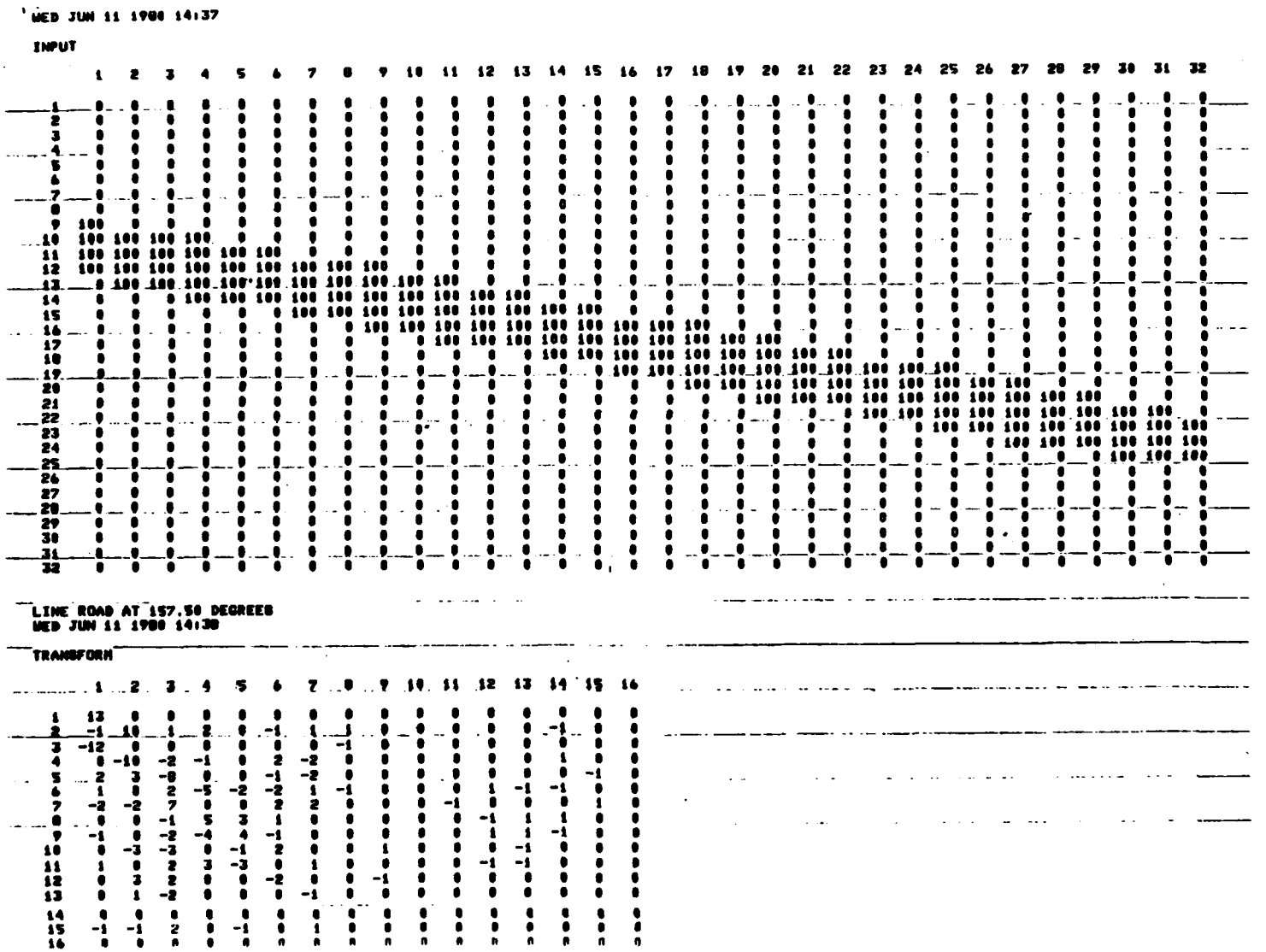


FIGURE 17. Spatial Signature, Recognition Result, and Walsh Transform for Line Road at 157.5 Degrees.

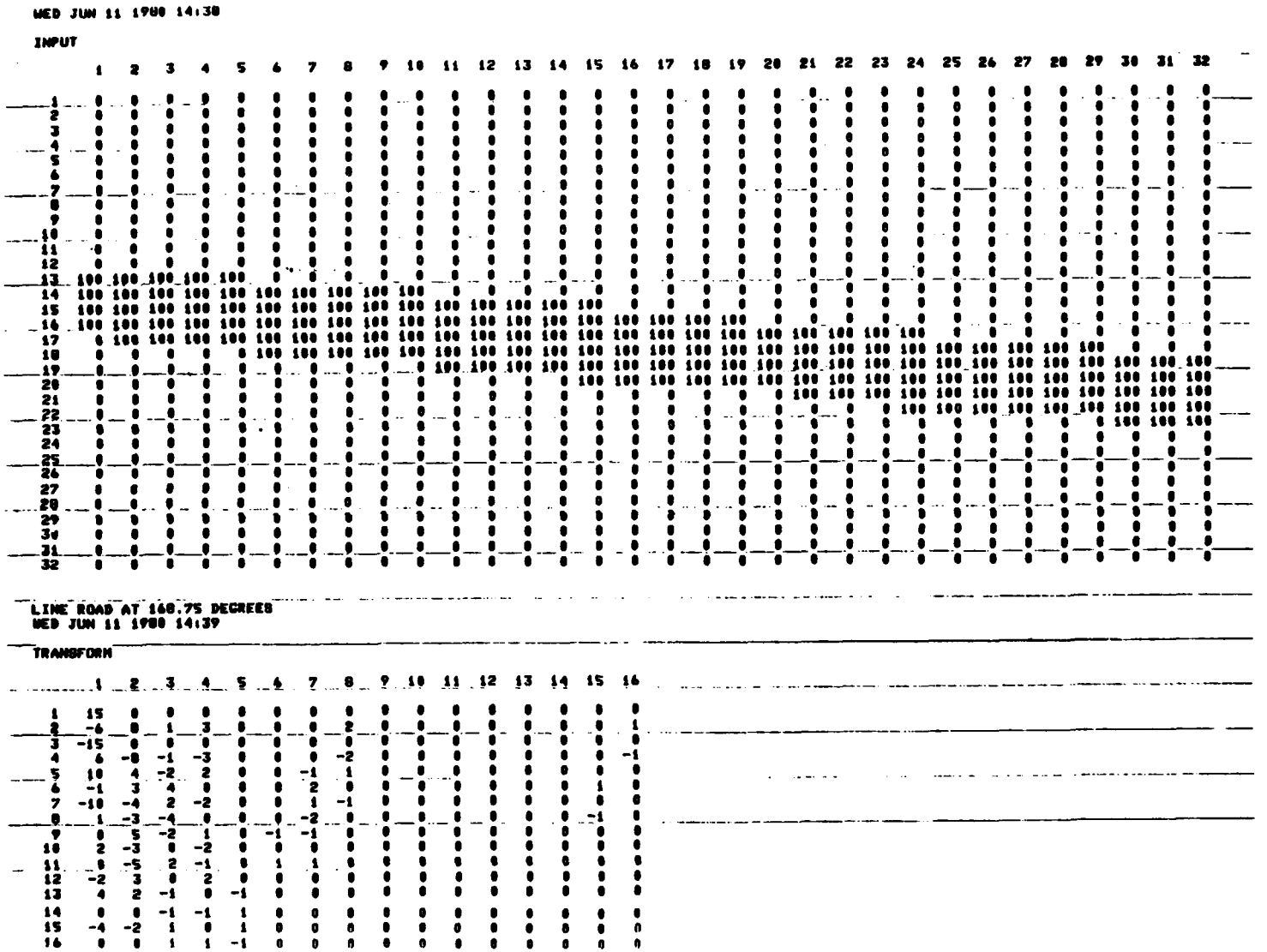


FIGURE 18. Spatial Signature, Recognition Result, and Walsh Transform for Line Road at 168.75 Degrees.

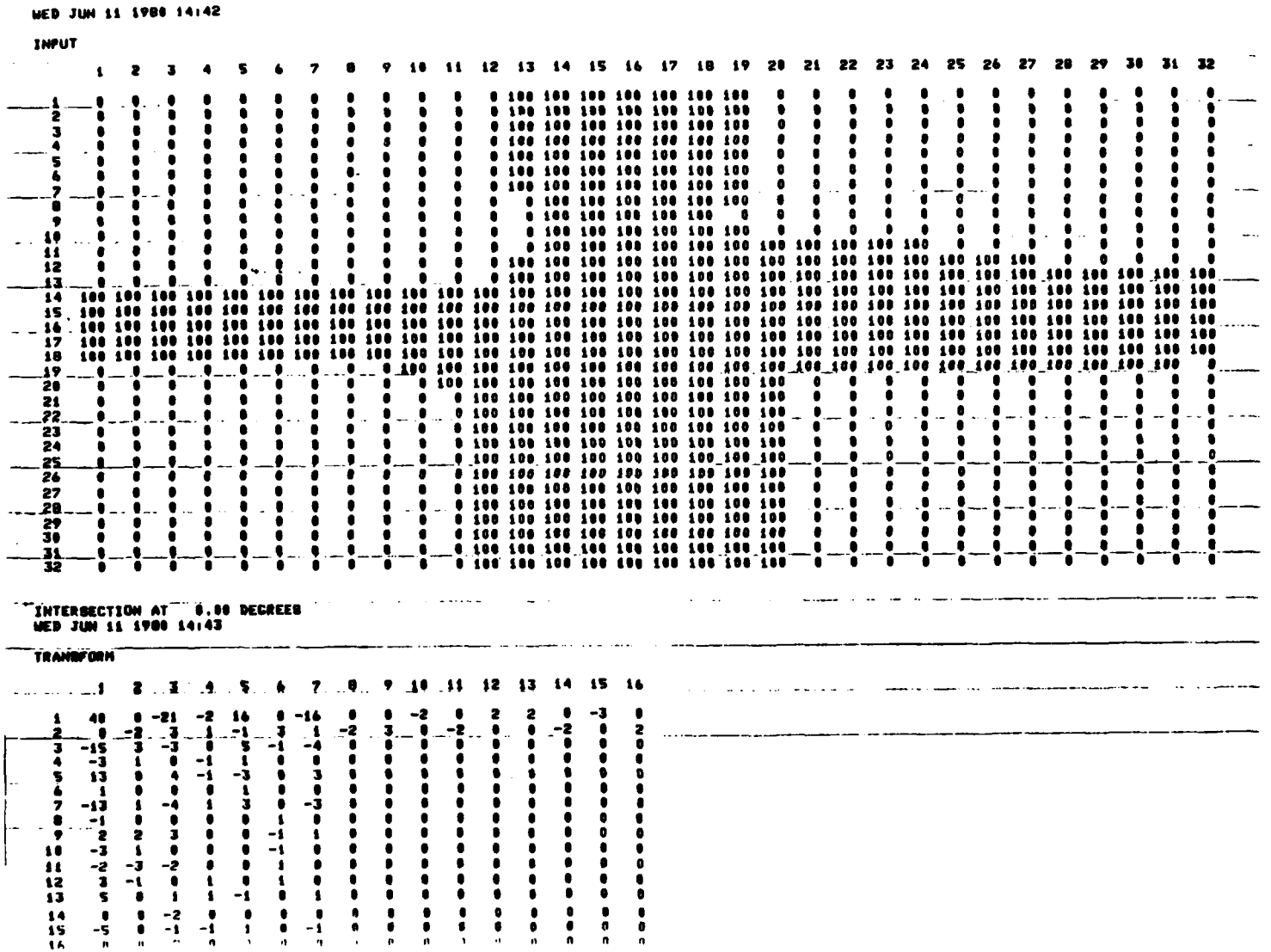
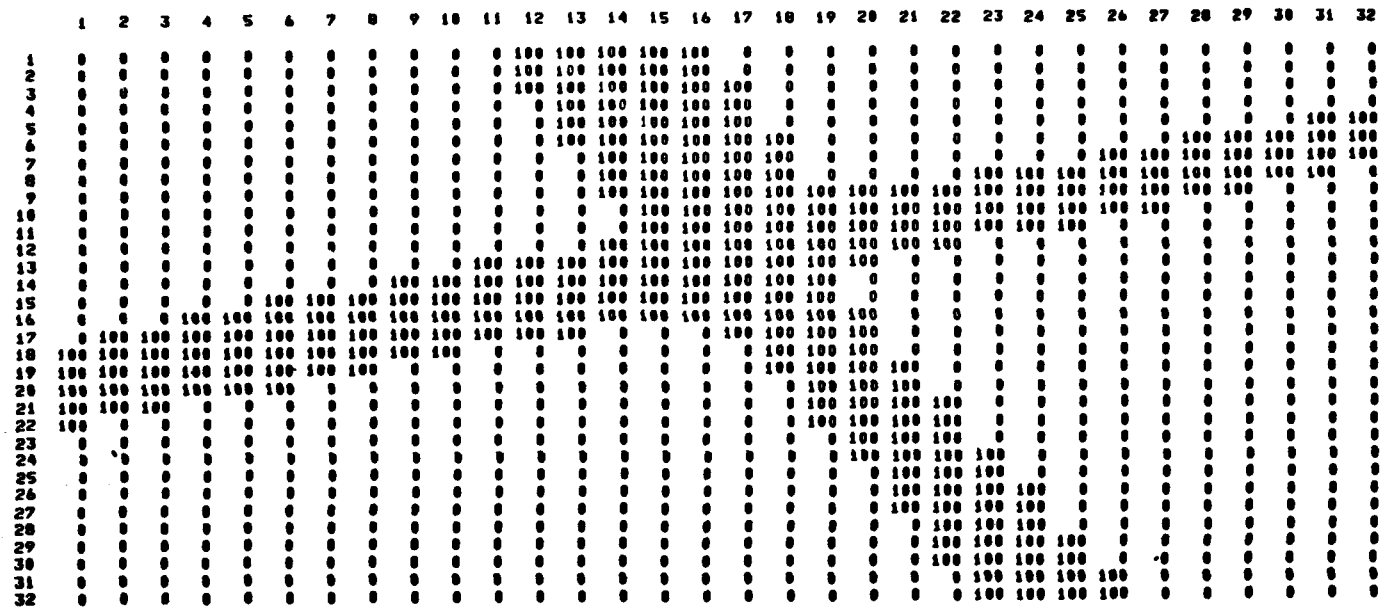


FIGURE 19. Spatial Signature, Recognition Result, and Walsh Transform for Road Intersection at 0 Degrees.

WED JUN 11 1980 14:46

INPUT



INTERSECTION AT 22.50 DEGREES
WED JUN 11 1980 14:47

TRANSFORM

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	25	-2	-10	3	3	3	-4	-2	0	0	0	-1	0	1	-1	0
2	6	1	-6	-11	7	-1	-8	-1	2	-1	-3	2	3	-1	-3	0
3	-7	-3	2	-8	-1	5	2	-6	3	-4	-2	3	0	0	0	0
4	0	4	5	0	5	-1	0	0	-2	1	0	0	1	-2	1	0
5	1	11	0	0	0	-4	-2	3	0	-3	0	1	-2	0	0	0
6	-5	5	-5	-1	0	0	1	-1	-3	1	2	0	1	-1	0	0
7	-5	-5	-2	0	-2	6	0	0	0	1	2	-1	0	2	-1	0
8	0	1	0	5	0	1	0	0	-1	1	0	-1	0	0	0	0
9	2	0	1	-1	-3	0	-1	0	1	0	-1	0	-1	0	0	0
10	2	-1	2	1	-1	1	0	0	0	1	0	0	0	1	0	0
11	-1	-1	0	0	1	1	0	1	0	0	1	0	0	2	0	0
12	0	0	-1	-1	0	0	0	0	0	0	-1	0	0	0	0	0
13	0	4	0	0	0	-2	0	0	0	0	1	0	-1	0	0	0
14	-2	2	0	1	0	0	0	-3	-1	0	1	-1	1	-1	0	0
15	-2	-1	0	-1	0	2	0	0	0	-1	0	0	0	1	0	0
16	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0

FIGURE 20. Spatial Signature, Recognition Result, and Walsh Transform for Road Intersection at 22.5 Degrees.

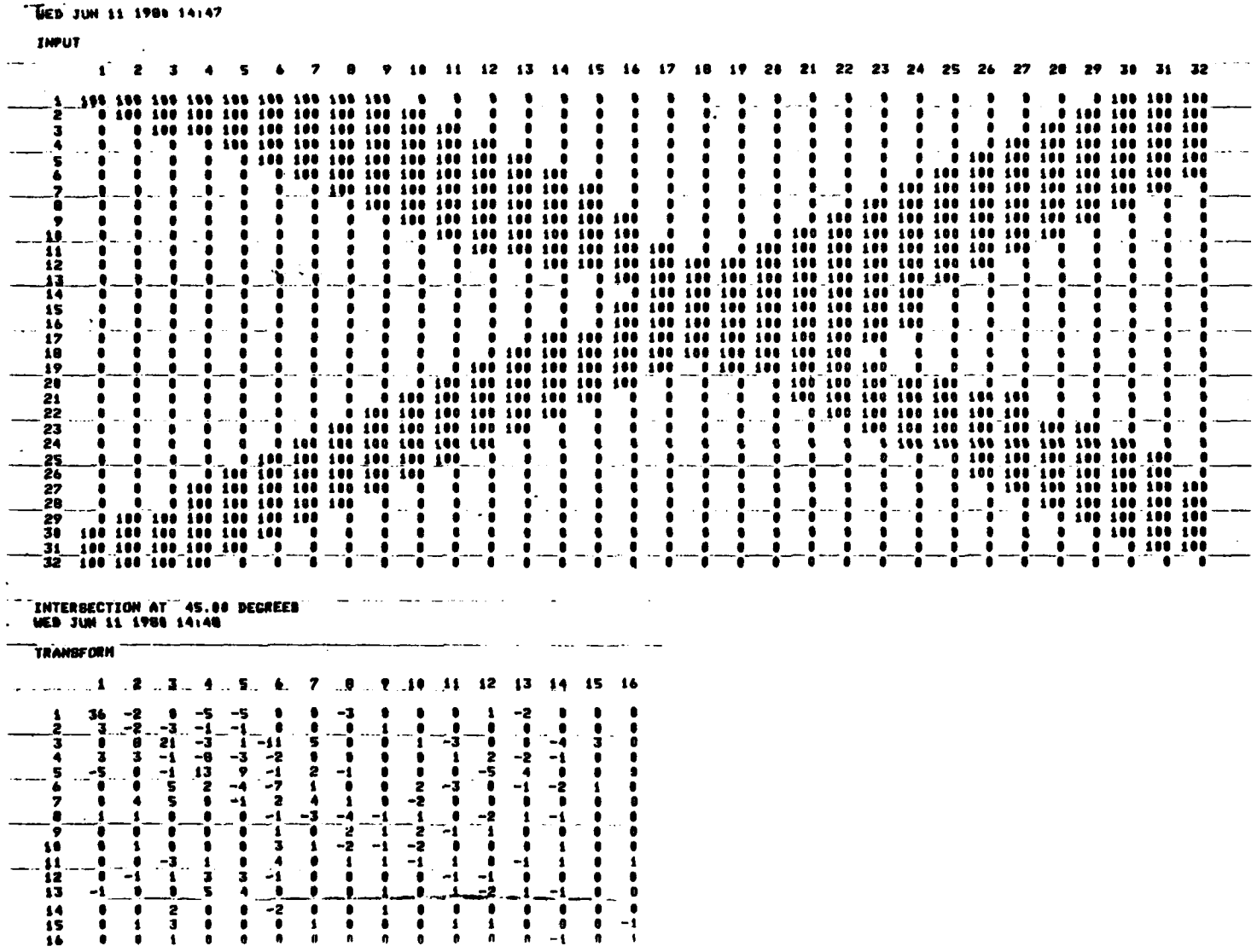


FIGURE 21. Spatial Signature, Recognition Result, and Walsh Transform for Road Intersection at 45 Degrees.

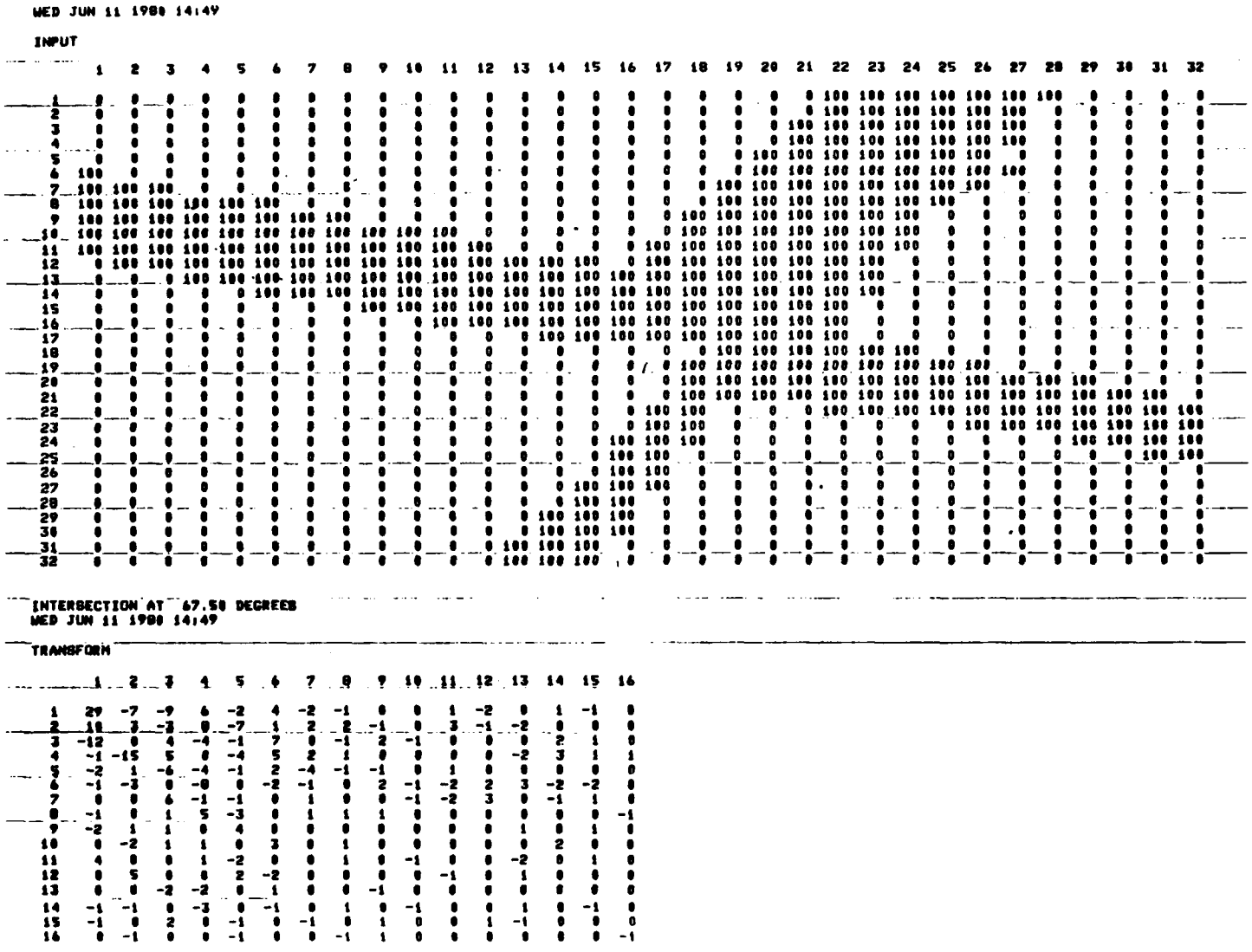


FIGURE 22. Spatial Signature, Recognition Result, and Walsh Transform for Road Intersection at 67.5 Degrees.

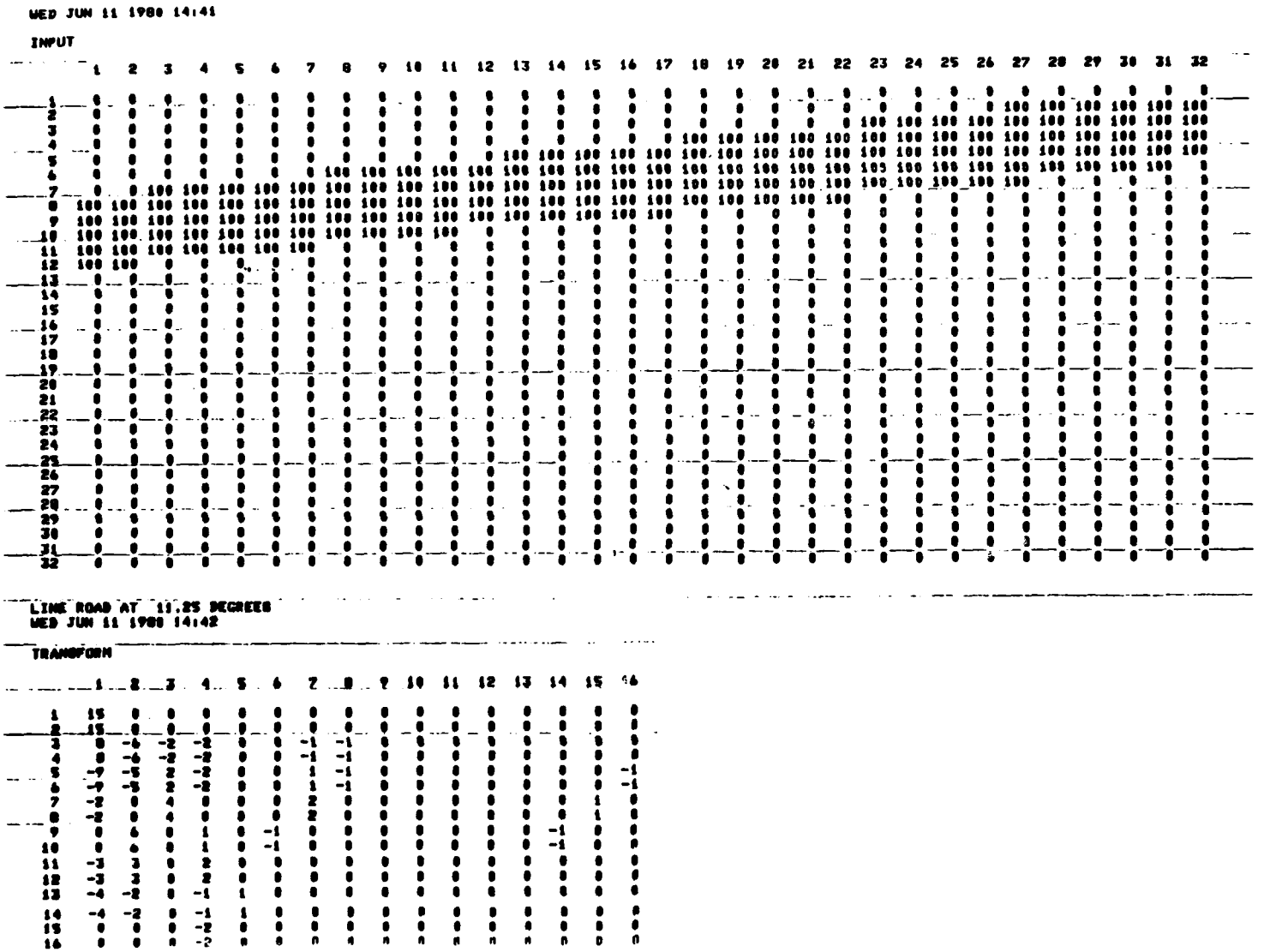


FIGURE 23. Spatial Signature, Recognition Result, and Walsh Transform for Line Road at 11.25 Degrees, and Translated to the Top of Window.

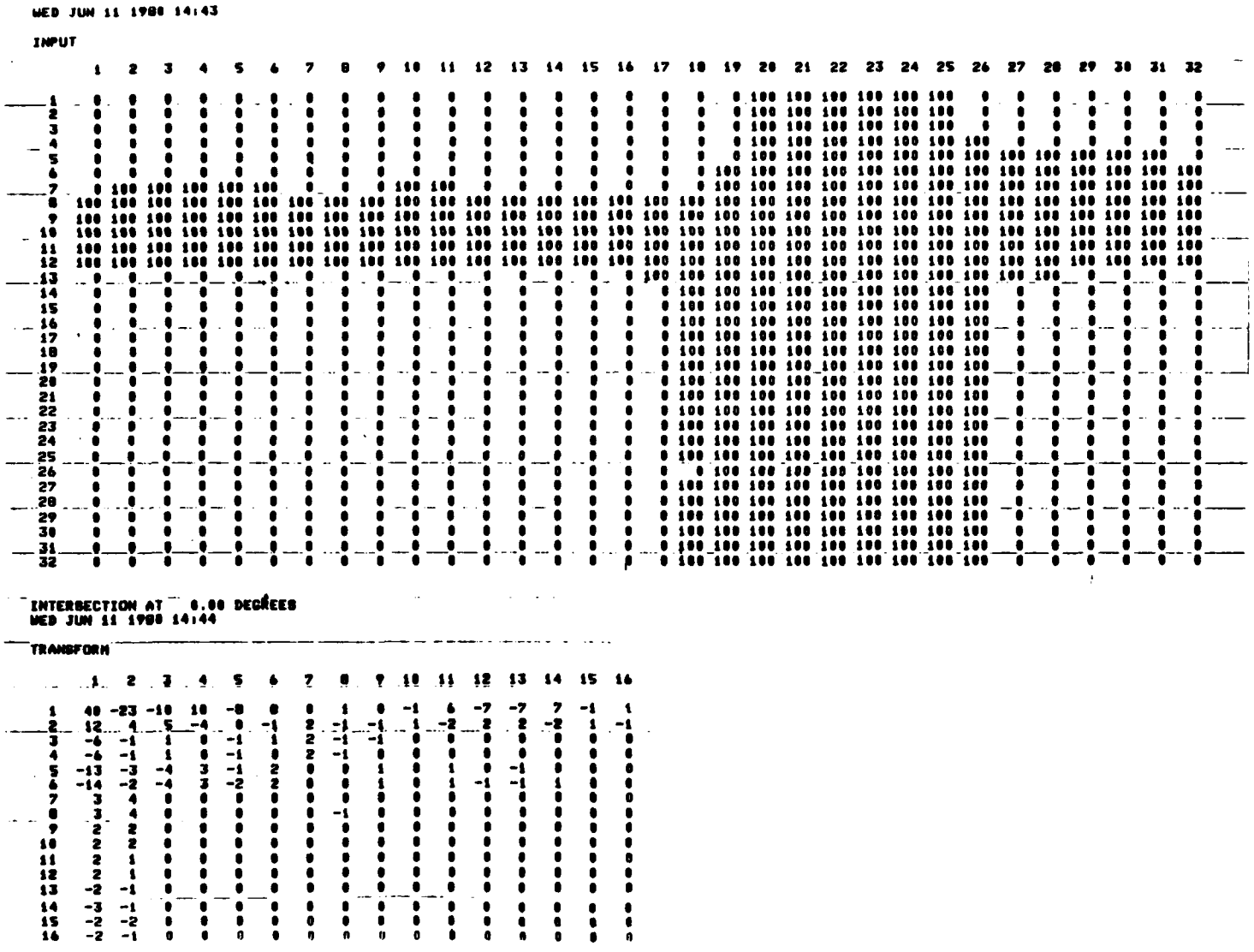


FIGURE 24. Spatial Signature, Recognition Result, and Walsh Transform for Road Intersection at 0 Degree, and Translated to the Right of Window.

APPENDIX

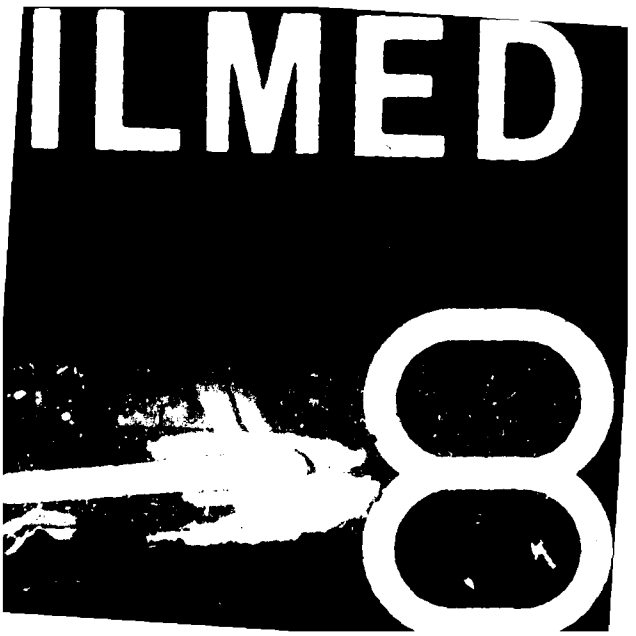
SUBROUTINE MATCH

```
FTN4,L
      SUBROUTINE MATCH (IXFRM,CONS,LUOT,INBUF)
      DIMENSION IXFRM(1024),CONS(20,16),COLM(16),INBUF(1024)
      ITOT=0
      DO 20 J=1,8
      ISUM=0
      DO 10 I=1,16
   10 ISUM=ISUM+IABS(IXFRM((I-1)*16+J))
      COLM(J)=ISUM
   20 ITOT=ITOT+ISUM
      DO 28 J=9,16
      ISUM=0
      DO 26 I=1,16
   26 ISUM=ISUM+IABS(IXFRM((J-9)*16+I))
      COLM(J)=ISUM
   28 ITOT=ITOT+ISUM
C
C SEE IF INTERSECTION
C
      A=ABS(COLM(1)-IXFRM(1))/IABS(IXFRM(1))
      B=ABS(COLM(9)-IXFRM(1))/IABS(IXFRM(1))
      IF (A.GT.0.7 .AND. B.GT.0.7 .AND. COLM(1).GE.50.
     * .AND. (COLM(9).GE.50)) GOTO 800
C
C COMPUTE DIAGONAL
C
      IDIAG=0
      DO 900 I=1,5
  900 IDIAG=IDIAG+IXFRM((I-1)*16+I)
      AT1=IABS(IXFRM(19))
      AT2=IABS(IXFRM(18))
      AT3=IABS(IXFRM(34))
      AT4=IABS(IXFRM(35))
      AT5=IABS(IXFRM(1))
      IF (((AT1/AT5).GT.0.35 .AND. (AT2/AT5).LT.0.3 .AND.
     * (AT5+AT1).GT.40)
     *.OR. ((AT3/AT1).GT.0.35 .AND. (AT2/AT5).LT.0.3 .AND. (AT5+AT3)
     *.GT.40) .OR. (IDIAG.GT.40 .AND. (AT4/AT5).GT.0.35 .AND.
     *(AT2/AT5).LT.0.3)) GOTO 810
C
C
C COMPUTE QUADRANTS TO DETERMINE IF ANGLE IS LESS THAN 90 DEGREES
C OR IF IT IS BETWEEN 90 AND 180 DEGREES
C
C
      M1=0
      M2=0
      DO 120 I=0,15
      DO 100 J=1,16
  100 M1=M1+INBUF(I*32+J)
      DO 110 J=17,32
  110 M2=M2+INBUF(I*32+J)
  120 CONTINUE
      M3=0
      M4=0
```

```
      DO 150 I=16,31
      DO 130 J=1,16
  130 M3=M3+INBUF(I*32+J)
      DO 140 J=17,32
  140 M4=M4+INBUF(I*32+J)
  150 CONTINUE
C
C TEST ONE
C
      K=0
      IF (M2.NE.0 .AND. M3.NE.0 .AND. ((M1.EQ.0 .AND. M4.NE.0) .OR.
     *(M4.EQ.0 .AND. M1.NE.0))) K=1
      IF (M1.NE.0 .AND. M4.NE.0 .AND. ((M2.EQ.0 .AND. M3.NE.0) .OR.
     *(M3.EQ.0 .AND. M2.NE.0))) K=8
      IF (K .NE. 0) GOTO 29
C
C TEST TWO
C
      IF (M1.NE.0 .OR. M2.NE.0 .OR. M3.EQ.0 .OR. M4.EQ.0) GOTO 300
      M3=0
      M4=0
      DO 210 I1=16,31
      DO 200 J1=1,16
      M3=M3+INBUF(I1*32+J1)
      IF (M3 .GE. 1000) GOTO 220
  200 CONTINUE
  210 CONTINUE
  220 DO 240 I2=16,31
      DO 230 J2=17,32
      M4=M4+INBUF(I2*32+J2)
      IF (M4 .GE. 1000) GOTO 250
  230 CONTINUE
  240 CONTINUE
  250 M3=I1*32+J1
      M4=I2*32+J2-16
      K=8
      IF (M3 .GE. M4) K=1
      GOTO 29
  300 IF (M3.NE.0 .OR. M4.NE.0 .OR. M1.EQ.0 .OR. M2.EQ.0) GOTO 400
      M1=0
      M2=0
      DO 320 I1=0,15
      DO 310 J1=1,16
      M1=M1+INBUF(I1*32+J1)
      IF (M1 .GE. 1000) GOTO 325
  310 CONTINUE
  320 CONTINUE
  325 DO 340 I2=0,15
      DO 330 J2=17,32
      M2=M2+INBUF(I2*32+J2)
      IF (M2 .GE. 1000) GOTO 350
  330 CONTINUE
  340 CONTINUE
  350 GOTO 250
C
```

```
C TEST THREE
C
  400 IF (M1.NE.0 .OR. M3.NE.0 .OR. M2.EQ.0 .OR. M4.EQ.0) GOTO 500
      M2=0
      M4=0
      DO 420 I1=17,32
      DO 410 J1=0,15
      M2=M2+INBUF(J1*32+I1)
      IF (M2 .GE. 1000) GOTO 430
  410 CONTINUE
  420 CONTINUE
  430 DO 450 I2=17,32
      DO 440 J2=16,31
      M4=M4+INBUF(J2*32+I2)
      IF (M4 .GE. 1000) GOTO 460
  440 CONTINUE
  450 CONTINUE
  460 GOTO 250
  500 IF (M2.NE.0 .OR. M4.NE.0 .OR. M1.EQ.0 .OR. M3.EQ.0) GOTO 600
      M1=0
      M3=0
      DO 520 I1=1,16
      DO 510 J1=0,15
      M1=M1+INBUF(J1*32+I1)
      IF (M1 .GE. 1000) GOTO 530
  510 CONTINUE
  520 CONTINUE
  530 DO 550 I2=1,16
      DO 540 J2=16,31
      M3=M3+INBUF(J2*32+I2)
      IF (M3 .GE. 1000) GOTO 560
  540 CONTINUE
  550 CONTINUE
  560 GOTO 250
C
C TEST FOUR
C
  600 IF (M1.EQ.0 .OR. M2.EQ.0 .OR. M3.EQ.0 .OR. M4.EQ.0) GOTO 700
  620 IF (IXFRM(18) .LE. 0) K=1
      IF (IXFRM(18) .GT. 0) K=8
      GOTO 29
C
C TEST FIVE
C
  700 IF (M2.EQ.0 .AND. M3.EQ.0 .AND. ((M1.NE.0 .AND. M4.EQ.0) .OR.
     *(M4.NE.0 .AND. M1.EQ.0))) K=1
      IF (M1.EQ.0 .AND. M4.EQ.0 .AND. ((M2.NE.0 .AND. M3.EQ.0) .OR.
     *(M3.NE.0 .AND. M2.EQ.0))) K=8
      IF (K .NE. 0) GOTO 29
      WRITE (1,710)
  710 FORMAT (' IMAGE DOES NOT FIT ANY TESTS')
      RETURN
C
C ROAD INTERSECTIONS
C
```

```
  810 MINNUM=19
      GOTO 65
  800 K=17
C
C FIND CLOSEST MATCH
C
   29 AMIN=1000.
      L=3
      IF (K.EQ.1 .OR. K.EQ.8) L=8
      DO 40 I=K,K+L
      DIF=0.
      IF (I .EQ. 19) GOTO 40
      DO 30 J=1,16
   30 DIF=DIF+(COLM(J)/ITOT-CONS(I,J))**2
      IF (DIF .GE. AMIN) GOTO 40
      AMIN=DIF
      MINNUM=I
   40 CONTINUE
      IF (MINNUM .GT. 16) GOTO 60
      IF (MINNUM .LT. 8) ANGLE=MINNUM*11.25
      IF (MINNUM .EQ. 8) ANGLE=0.
      IF (MINNUM .GT. 8) ANGLE=(MINNUM-1)*11.25
      WRITE (LUOT,50) ANGLE
   50 FORMAT (' LINE ROAD AT ',F6.2,' DEGREES')
      RETURN
   60 IF (MINNUM.EQ.17) GOTO 65
      C=0
      D=0
      DO 62 I=1,32
      C=C+INBUF(I)
      D=D+INBUF(992+I)
      IF (C.EQ.300 .OR. D.EQ.300) GOTO 63
   62 CONTINUE
   63 MINNUM=18
      IF (D .GT. C) MINNUM=20
   65 ANGLE=(MINNUM-17)*22.5
      WRITE (LUOT,70) ANGLE
   70 FORMAT (' INTERSECTION AT ',F6.2,' DEGREES')
      RETURN
      END
      END$
```


ILMED
8